Ontario Tree Improvement and Forest Biomass Institute

Forest Research 1983 - 1985

Review of selected research activities for the period 1 January 1983 - 31 December 1985 with some reference to 1982

Edited by:
D. Gillmeister
and D. Bates

Ontario Tree Improvement and
Forest Biomass Institute

Ontario
Ministry of Natural Resources

Hon. Vincent G. Kerrio
Minister

Mary Mogford
Deputy Minister

ISSN 0704-2809

©1987, Queen's Printer for Ontario

Additional copies of this publication may
be obtained from:

Ontario Tree Improvement and
Forest Biomass Institute
Ministry of Natural Resources
Maple, Ontario L0J 1E0
(416) 832-2761

TABLE OF CONTENTS

INTRODUCTION..... 1

RESEARCH PROGRAMS..... 3

TREE IMPROVEMENT

Physiological Genetics..... 3

Wood Quality of Jack Pine..... 3

Isozyme Studies..... 4

White Spruce Seed Orchard Genotyping..... 4
White Pine Clonal Identification..... 4
Jack Pine Populations and Gene Linkage..... 5

Cone Induction..... 5

$GA_{4/7}$ Spraying..... 5
Intravascular Application of $GA_{4/7}$..... 6
Girdling and Root Pruning..... 6

Biotechnology..... 7

Haploid Plant Induction..... 7
In Vitro Propagation..... 8

Hardwood Tree Improvement..... 9

Hybrid Poplar/Willow Minirotations..... 9

Breeding of Fast-Growing Hybrids..... 11

Poplar Breeding..... 11
Studies in Native Poplar Species..... 11
Trembling Aspen..... 11
Balsam Poplar..... 12
Poplar Hybridization..... 12
Poplar Trials..... 13
Willow Collection and Hybridization..... 13
Alder and Birch Hybridization..... 13
Introduction of New Species and Clones..... 14

Larch..... 14

Stand Location, Mapping and Assessment..... 14
Clone Bank at OTIFBI..... 15
Genetic Architecture Study:
Rooted Cuttings Trial..... 15
Annotated Bibliography..... 15

Spruce..... 16

Spruce Hybridization..... 16
Outplanting of Clonal Interspecific Hybrids..... 19

TREE IMPROVEMENT (CONTINUED)

Norway Spruce..... 19

Breeding Orchard..... 19
Genetic Test..... 19
Annotated Bibliography..... 20

White Pine..... 20

White Pine Hybridization..... 20
Progeny Trials..... 20

SEED RESEARCH

Accelerated Transplants..... 21
Coniferous Seed Production..... 22
White Spruce Growth Related to Seed Origin..... 23
White Spruce Gene Pool..... 24

STOCK PRODUCTION

Container Seedling Production..... 24

Hardening Regimes for Overwintering Spruce Container Seedlings..... 24
Regional Testing Laboratories..... 25
Field Performance of Extended Greenhouse Stock..... 25
Bud Development in Black Spruce Container Seedlings..... 26
Extended Greenhouse Culture for Jack Pine..... 26

Nursery Stock Stress Resistance..... 27

Plant Moisture Stress..... 27
Root Growth Capacity..... 27
Antitranspirants..... 27
Preconditioning Nursery Stock for Stress Tolerance..... 28

Physiology..... 28

Dormancy and Frost Hardiness..... 28

Production and Performance of Coniferous Planting Stock.... 29

Container Stock vs. Bare-Root Stock..... 29
Irregular Growth of Outplanted Red Pine..... 30
Stock Characterization and Mulches..... 30
Stock-Type and Site Testing..... 31
Conifer Storage and Handling..... 31
Larch Storage..... 32
Continuous Planting..... 32
Stock Conditioning..... 33
Stock Grading..... 33
Lifting and Root Pruning..... 33

STOCK PRODUCTION (CONTINUED)

Production and Performance of Coniferous Planting Stock

Water Stress Effects on Biomass Accumulation..... 34
Nursery Irrigation Based on the Atmospheric Demand for Evapotranspiration..... 35

REGENERATION

Rejuvenating Older and Damaged Stands..... 36

Yellow Birch/Sugar Maple Regeneration and Recruitment..... 36
Rejuvenation of Poplar Stools for Improved Production..... 38
Regenerating Red Oak..... 39
Hardwood Sprouts for Timber..... 39
Quality and Variability of Aspen Regeneration..... 39
Effect of Cutting Method on Natural Aspen and Artificial Spruce Regeneration..... 41
Boreal Mixedwood Successional Trends..... 41
Spruce-Fir Stand Dynamics and the Spruce Budworm..... 42

Biomass Culture and Silviculture..... 43

Coniferous Biomass Productivity..... 43
Species Introduction for Short Rotation and Biomass Projects..... 44
Effluent Disposal Combined with Intensive Silviculture..... 45
Automatic Planter for Poplar Cuttings..... 47

STAND MANAGEMENT

Hardwood..... 48

Sugar Maple Quality Dynamics..... 48
Tolerant Hardwoods: Growth and Yield..... 49
Thinning of Hardwood Stands..... 49
Dynamics of Stand Structure and Stocking in Uneven-Aged Tolerant Hardwoods..... 50
Growth of Tolerant Hardwoods after Commercial Logging..... 51
Development of Tolerant Hardwood Polewood after Pre-Commercial Thinning..... 52
Models for the Cutting and Response of Hard Maple in Hardwood or Mixedwood Stands..... 52
Algonquin Regional Growth Study..... 52
Tending High-Quality Stands..... 53

Softwood..... 53

Natural White Pine Management..... 53
Jack Pine Plantations: Growth and Yield..... 54

STAND MANAGEMENT (CONTINUED)

Softwood

Red Pine Plantations: Growth and Yield..... 55
Spruce Plantations: Growth and Yield..... 56
Balsam Fir: Growth and Yield..... 57

Mixedwood..... 59

Mixedwood Forest Growth Models..... 59
Thinning Aspen in the Boreal Mixedwood Forest..... 59

Growth Measurement Techniques..... 60

Automated Ring Measurement System.. 60
Stem Growth and Development Patterns..... 60

SITE

Regional Ecology..... 61

Site Regions of Northeastern North America..... 61
Climatic Ecoregions of Canada..... 62
Site Regions of Ontario..... 62
Regional Forest Ecology, Northeast China..... 62
Consultation, Forest Soils, Burma..... 62

Forest Ecosystems..... 63

Acid Precipitation..... 63
Productivity and Nutrient Cycling
in Spruce Forest Ecosystems..... 65
Sensitivity of Species and Cultivars to
General and Seasonal Climatic Conditions..... 67
Red Pine Growth Studies..... 68
Forest Ecosystem Classification..... 69

Modeling..... 70

Georeferencing Database..... 70

STAFF PARTICIPATION

Papers and Posters Presented..... 71
COJFRC Information Session..... 76
University Involvements..... 76
Committees..... 77
External Contracts..... 78
Other Activities..... 79
Visitors to Institute..... 79
Publications..... 80

ORGANIZATION AND STAFF

Staff Changes..... 90
Organization Chart..... 92

LIST OF TABLES

Table		
1	Jack pine wood quality summarized by district mean value...	3
2	Number of permanent sample plots in tolerant hardwood stands by region and district.....	49
3	Percentage of basal area growth rates by periods of treatment.....	50
4	Location of pure red pine and mixed red pine/white pine permanent sample plots by region and district.....	55
5	Distribution of spruce permanent sample plots by district in the province of Ontario.....	56
6	Distribution of plots by site disturbance/ site preparation, stock type and tending history.....	58
7	Growth and performance at Flesherton of five Euramerican clones ranked according to size in 1983, at 13 years after planting.....	66

INTRODUCTION

Never in Ontario's history has there been so much emphasis on forestry, or such a need for first-class forest management. The forest industry and governments alike are now making unprecedented investments in Ontario's forestry future. It is a great challenge to us all to maintain, and hopefully to enhance, the tremendous economic benefits which we derive from our forests, especially in terms of jobs and value added.

However, forestry is a risky business. It usually takes several generations to grow trees to harvestable size, and forest managers must cope with the vagaries of weather, fire, insects and disease. Similarly, dramatic shifts in consumer demand mean changes in the type and quality of wood required for the manufacture of a wide and rapidly expanding range of products. To reduce all these uncertainties, we need knowledge, and only research can provide this much-needed information in an organized, timely and cost-effective way.

We at this Institute are proud of our historical research achievements which have provided new understanding in ecology, site classification, tree improvement, nursery practices, and silviculture. These research results have been applied not only in Ontario, but also throughout many parts of the world. Widely used practices originating at Maple include the Brohm Seeder, Extended Greenhouse Culture, the TRIM system and a comprehensive forest ecosystem classification system. We have developed an outstanding team of scientists and technicians who are very excited about the prospects of our current work in genetics, biotechnology, physiology and silviculture. These projects promise to provide great help to forest managers as we seek to shorten rotations, increase yields, and improve the quality of what is undoubtedly Ontario's most important natural resource.

D.P. Drysdale
General Manager
OTIFBI

Physiological Genetics

Wood Quality of Jack Pine

Variation Within Trees:

A study was conducted in cooperation with Abitibi Price and the University of Toronto to ascertain the amount of variation in selected wood quality parameters within jack pine trees, and to give guidelines for wood character sampling. Ten trees from each of two stands near Chapleau, Ontario, were sampled and wood parameters were measured from discs at several positions along the bole. Data indicated that there was a strong correlation between specific gravity at D.b.h. and specific gravity at other levels. As a result, specific gravity measurements have been standardized for comparative purposes at D.b.h. Stem analysis of sections every 30 cm indicated that trees in this sample with high heartwood and extractive content appeared to be less vigorous and had smaller live crowns than those with low heartwood and extractive content.

Variation Between Plus Trees:

The OMNR has embarked upon a jack pine plus tree selection program, and since 1982, plus tree selections have been examined for wood quality. In cooperation with the Northern and Northwestern Regions of OMNR and the University of Toronto, OTIFBI has analysed 1 044 plus trees for several wood quality parameters measured from breast-height discs. Included in measurements are: per cent moisture content, per cent heartwood, juvenile specific gravity (<20 years), mature specific gravity (>20 years), specific gravity at 1/2 cambium, specific gravity at five, 15 and 25 years, tracheid length at five, 15 and 25 years and 1/2 cambium. This information is providing baseline data for decisions regarding inclusion of wood quality parameters into selection criteria. High levels of variability are apparent for all measured characters. In addition, it is apparent that per cent heartwood shows variation that is independent of tree age. A partial summary of data expressed by district mean value is in Table 1.

TABLE 1 Jack pine wood quality summarized by district mean value

District	No. of trees	% Heart wood	Juvenile Specific Gravity	Mature Specific Gravity	5 Year Tracheid Lengths	15 Year Tracheid Lengths	25 Year Tracheid Lengths
Kirkland Lk.	104	43.2	.403	.454	1.72	2.85	3.27
Gogama	100	28.9	.397	.440	1.69	2.83	3.29
Ignace	22	37.6	.417	.465	1.69	2.65	3.12
Chapleau 331	126	38.2	.401	.450	1.65	2.87	3.30
Chapleau 431	150	35.3	.396	.442	1.53	2.82	3.29
Hearst	49	36.0	.394	.439	1.93	2.96	3.40
Kapuskasing	25	47.3	.394	.451	1.96	2.90	3.42

(G. Buchert)

Isozyme Studies

White Spruce Seed Orchard Genotyping

The white spruce clones included in the Glencairn Seed Orchard were genotyped by isozyme analysis in order to provide genetic information for pollen flow, pollen grain competition and inheritance studies. Electrophoresis of female gametophyte tissue from 84 clones revealed 13 polymorphic loci useful for future studies, and four monomorphic loci. Subsequent computer sorting indicated a number of clones which were homozygous at enough loci to provide definitive data on pollen competition in pollen mixes.

(G. Buchert)

George Buchert and Lynn Farintosh measure the growth of white spruce in the experimental planting at OTIFBI.

White Pine Clonal Identification

We used isozyme analysis to determine the clonal identification of ramets in a blister-rust resistant white pine seed orchard. The orchard clones have been selected for form and rust resistance for over 40 years, but identity of materials in the grafted orchard had been confounded. Needles were collected from each ramet and electrophoresed at Maple. Three loci, GOT-2,3, MDH-2 and MDH-3 were found to have diagnostic value. We analysed 1 043 ramets and found 52 unique gene combinations. Subsequent computer-generated maps of the orchard plotted ramet positions corresponding to the 52 isozyme genotypes. These maps

indicate the potential genetic management problems and give guidelines for roguing, thinning and controlled crossing within the orchard.

(G. Buchert)

Jack Pine Populations and Gene Linkage

Work on isozyme analysis has concentrated on jack pine, white pine and white spruce. Female megagametophyte analysis of 320 jack pine trees from 32 central Ontario stands gave no indication of population substructuring. Only about 5% of the total genetic variability detected could be attributed to among-stand differences. However, the average stand heterozygosity was relatively high (H=0.15), indicating a high level of genetic variability among trees within stands. Twenty loci out of 27 loci studied in 13 enzyme systems were polymorphic. Chi-square analysis of doubly heterozygous jack pine individuals indicated measurable linkage between the following pairs of loci:

6 PGD-2/IDH-2; AAT-2,3/DIA-2; PGI-2/AAT-1; MDH-3/DIA-2; AAT-2,3/AAT-1; 6PGD-3/ACO-1; PGI-2/ADH-1; ACPH-2/DIA-1; MDH-3/AAT-4; AAT-1/ADH-1.

(G. Buchert)

Cone Induction

Application of gibberellic acid 4/7 ($GA_{4/7}$), girdling, root pruning and a combination of girdling and root pruning to enhance cone production has been carried out on selected trees in seed orchards or arboreta in black (*Picea mariana*), white (*P. glauca*), and Norway spruce (*P. abies*) for the last three to five years. The objectives were: i) to establish timing and period of application; ii) to determine the optimal concentration; and iii) to define the effect of repeated application.

$GA_{4/7}$ Spraying

Forty (40) white spruce trees representing five clones were sprayed biweekly with either a treatment solution containing 200 mg/L $GA_{4/7}$, 15% alcohol, and 0.05% Tween 20 or a control containing only alcohol and Tween 20 during two different periods: i) May, June, and July; and ii) June, July, and August. In 1984, trees sprayed in the first period produced significantly more cones (3 051 cones per tree) than the controls (1 647 cones per tree) while spraying in the second period was not effective (2 749 cones per treated tree vs. 2 947 cones per control tree). In both 1983 and 1985, the spraying did not stimulate any cone production. It appeared that the treatment could not guarantee good cone crops.

Four branches from each of 24 white spruce trees representing six clones were sprayed biweekly with four different concentrations of $GA_{4/7}$ solution (0, 200, 400, and 800 mg/L) from May to August for three years. The concentration at 800 mg/L significantly increased cone production and resulted in an average of 204 cones per branch in 1984 (149 cones at 0 mg/L, 180 at 200, 187 at 400). Treatment at any of the four concentrations was ineffective in both 1983 and 1985.

(R.H. Ho)

Intravascular Application of $GA_{4/7}$

$GA_{4/7}$ at 100 ug in 5 ml of 5% alcohol solution was applied weekly to black spruce (four ramets per clone, five clones) and white spruce trees (four ramets per clone, six clones) through cut branch ends at different durations (two, four and eight weeks) in May and June for the last five years (1980-1984). Good cone crops occurred in 1984, fair in 1981 and 1982, and poor in 1983 and 1985.

In black spruce, an average of 127, 155, and 118 cones per ramet per year was produced on trees treated for two, four and eight weeks respectively, while the controls were treated with 5 ml of 5% alcohol for eight weeks and produced an average of 82 cones per ramet per year. In white spruce, the production per ramet per year for trees treated for two, four and eight weeks, and the controls, averaged 536, 496, 431, and 458 cones, respectively.

It appeared that 100 ug of $GA_{4/7}$ per tree per week might be adequate to enhance cone production on small trees (under 2 m; average height for black spruce was 1.6 m in 1980 and 2.8 m in 1984; average height for white spruce was 2.0 m in 1980 and 4.0 m in 1984). As trees grow in height and foliage, an escalation of $GA_{4/7}$ concentration in application would be necessary to stimulate cone production.

The duration of application may require six weeks, and the treatment should begin at the time of bud scale initiation and end after bud-type differentiation in late June. Reproductive buds bore significantly fewer bud scales than vegetative buds. Therefore, bud-type determination could have occurred biochemically before or during the process of bud scale initiation. Bud scale initiation could have terminated earlier or could have occurred at a slower pace in the reproductive buds than in the vegetative buds.

(R.H. Ho)

Girdling and Root Pruning

Twenty-four (24) white spruce trees representing eight ramets per clone for three clones were selected for the study. Six trees were used as controls, and the other 18 trees were either girdled, root-pruned, or both for the last five years (1980-1984). Two half-moon overlapping girdles which were opposite each other and placed 30 cm apart were applied to the trunk. In root pruning, roots were severed in early May along the 60 cm radius of the trunk and about 35 cm in depth.

An average of 288, 368, 314, and 519 cones per ramet per year were produced from the control, girdled, root-pruned, and girdled and root-pruned trees, respectively. In a good crop year, a combination of girdling and root pruning appeared to be the most effective in stimulating cone crops, while in a fair crop year, root pruning would give a good result. However, in a poor crop year, none of the treatments stimulated cone crop.

In 1983, the same girdle treatment was given to one half of 22 Norway spruce trees representing 11 clones. In the following year, production in the treated trees was significantly increased to an average of 72 cones per tree, while the controls produced an average of 34 cones per tree. However, the treatment resulted in chlorosis of foliage. Recovery occurred in the year following cone production.

(R.H. Ho)

Biotechnology

In *in vitro* culture, there were two projects: i) haploid plant induction through anther culture in poplars (*Populus*), and ii) vegetative propagation through explant culture in poplars, black spruce, white spruce, jack pine (*Pinus banksiana*), and eastern white pine (*P. strobus*). The first project was aimed at production of isogenic pure lines for breeding and the second at development of an *in vitro* technique for nursery operation.

Rong Ho and Yesoda Raj examine the progress of a poplar haploid plantlet produced by tissue culture.

Haploid Plant Induction

Poplar anthers were incubated on a medium in petri dishes when the pollen mother cells in anthers had developed to the mononucleate microspore stage. The medium was based on Murashige and Skoog (MS) medium and supplemented with 2 mg/L 2,4-D and 1 mg/L kinetin. After two months of culture in darkness, the anthers with calli in their cavities were transferred to MS medium supplemented with 1 mg/L BAP and 0.2 mg/L NAA under a 16-hour photoperiod with temperature at 25°C during the day and 15°C at night. In a couple of months, adventitious shoots regenerated from calli and the shoots were rooted in modified MS medium (the macronutrients are one half of the MS medium) containing 0.02 mg/L NAA when they reached 3 cm in height. MS medium supplemented with 0.2 mg/L BAP and 0.2 mg/L NAA was used in the subsequent transfers of calli with adventitious shoots. Plantlets have been produced from *P. angulata*, *P. deltoides*, *P. nigra*, *P. jackii*, *P.* x *euramericana*, and *P. maximowiczii* x *deltoides*.

Embryoids have been produced from *P. alba*. Anthers at the described stage were incubated on MS medium supplemented with 1 mg/L kinetin in petri dishes, and the dishes were placed in an incubator in

darkness at a constant temperature of 25°C. After two months of culture, three embryoids were produced. One had three cotyledon primordia and a radicle which was connected to the anther with a short stalk. The stalk may function as a suspensor in embryogenesis. The primordia turned green after the embryoid was exposed to light. The second embryoid had an elongated stem with small leaves and a minute root, and the third was an albino with a couple of leaves. The origin of the embryoids is not known and requires further investigation.

(R.H. Ho and A.Y. Raj)

In Vitro Propagation

Seeds of Populus alba, P. grandidentata, P. nigra x P. maximowiczii, P. tremula and P. tremuloides were germinated aseptically on 0.6% Agar. After germination, the cotyledons were excised, sterilized and incubated directly on MS medium supplemented with 1 mg/L BAP and 0.2 mg/L NAA. Within 40 days, many adventitious shoots developed from proliferated cotyledons. The adventitious shoots were transferred to a rooting medium and the remaining calli were divided into many pieces and placed each in a jar. More adventitious shoots developed from these calli. The shoots developed roots in 10 days. These plantlets were washed of agar and planted in small pots, and hardened for about two weeks in a mist house. They were kept in a greenhouse and planted in the nursery in the spring. Over 1 000 plantlets could be produced in P. tremula and P. nigra x P. maximowiczii in four months and in P. alba, P. grandidentata and P. tremuloides in eight months.

Plantlets were also regenerated in P. deltoides x P. nigra, P. trichocarpa x P. angulata, P. alba x P. grandidentata and P. tremula from stem or leaf calli by incubating thin cross sections of young stem and pieces of young leaves from mature trees. Stem and leaf sections were first incubated on MS medium supplemented with 2,4-D and kinetin and the calli developed in 30 days. Calli were transferred to MS medium supplemented with BAP and NAA where adventitious shoots developed. Upon transfer of shoots to a rooting medium, they developed roots in 10 days.

Open-pollinated seeds of black spruce, white spruce, jack pine, and eastern white pine were germinated aseptically. After the cotyledons had emerged from the seed coats, the germinants were excised into three types of explants - epicotyls with intact cotyledons, cotyledon segments, and hypocotyl segments. Explants were incubated on Gresshoff and Doy (GD) medium supplemented with 10 mg/L BAP and 0.2 mg/L NAA for 40 days. Calli which regenerated from the explants and had primordia of adventitious shoots were transferred to 1/2 strength GD medium containing 1 mg/L BAP, 0.2 mg/L NAA and 1% activated charcoal. After a month of culture, they were transferred to 1/2 strength GD medium for shoot elongation. Adventitious shoots of about 1 cm in height were excised and treated with NAA to promote root primordial formation. The shoots were then rooted in 1/2 strength GD medium without growth regulator.

Plantlets have been produced from explants of the four species. Cotyledons of black spruce were most responsive to induction, while epicotyls were most responsive for white spruce, jack pine, and eastern white pine.

(R.H. Ho and A.Y. Raj)

Hardwood Tree Improvement

Hybrid Poplar/Willow Minirotations

Establishment Methods:

Over the past five years, a project to develop cost-efficient methods of establishing dense minirotations for chemical or energy production has met with considerable success. In this technique, dormant cuttings are horizontally planted in bulk (scatter planting) or in linear configurations in shallow trenches to reduce the high cost of dibble-planting.

Successive experiments have yielded progressively better results. For example, a "minimax" test at Midhurst in 1982 compared eight clones using a logarithmic series of cutting lengths (6 to 100 cm) in an incomplete block design. Survival, number of shoots per cutting, and dominant shoot length increased with cutting length. Analysis of variance of dominant shoot length per planted cutting indicated that both clonal and length effects were significant, but interactions were not.

A high-density scatter planting was established in 1982 using three poplar clones (DN-88, DN-157, NM-1) and three willow clones (SP-1, SAD-1, SB-1). Both mean shoot density and dominant shoot length increased over time with annual coppicing. After three growing seasons, shoot density was as high as 150 stems $.m^{-2}$ for willow and 86 stems $.m^{-2}$ for poplar, and average dominant shoot length ranged from 173 to 203 cm for poplar and 142 to 171 cm for willows. Rotation length has been increased to two years (in 1984 and 85 growing seasons) to study the effect of such high density on shoot survival and biomass production.

Additional plantings in 1983 and 1984 have confirmed these results for other clones. Such techniques may be applicable to the development of "poplar farms" and "energy forests" in the future. Results of these studies were presented at the International Poplar Congress held in Ottawa in 1984.

Spacing/Clonal Studies:

A spacing x rotation experiment, established at Allandale in 1972, was concluded with the harvesting of the 1984 production. This test involved hybrid poplar clone I-45/51 growing at four spacings (0.3 x 0.9, 0.3 x 2.4, 0.6 x 2.4, 1.2 x 2.4 m) and over three rotation lengths (one, two, and three years), in a randomized incomplete block design.

Over the 12 growing seasons, survival, average diameter and height (weighted by survival) decreased markedly at close spacings on one-year rotation and very little at the widest spacings on three-year rotation, there being a gradual improvement in performance with both increased spacing and cutting-cycle length.

Biomass productivity over the 12-year period was best (about 60 $odt.ha^{-1}$) at 0.3 x 2.4 m spacings over two- and three-year rotations and at 0.6 x 2.4 m spacing on the three-year cutting cycle. However, at the 12-year harvest, the two-year cutting cycle showed a decreasing productivity rate while all of the three-year rotations (including the

1.2 x 2.4 m spacings) showed consistent performance. The longer term prognosis would suggest that only the wider-spaced, longer rotations would maintain production. Further analyses will examine these results to suggest optimum management strategies.

In 1983, a hybrid poplar clonal x spacing study was established at Vespra for each of one-, two-, and three-year rotations. Five clones (DN-182, DN-87, MD-1, NM-6, DTAC-12) were planted in two replications at spacings of 0.3 x 1.0, 0.6 x 1.0, and 1.2 x 1.0 m, in an incomplete block design. An evaluation of productivity will be carried out after the 1989 growing season (i.e. after the first synchronous harvest of one-, two-, and three-year-old rotations).

In addition, a willow two-year-minirotation clonal test was established in 1983 at the Vespra site. Eight clones (SAC-1, SAD-1, SA-25, SP-1, SP-3, SH-3, SD-1, SV-1) were planted at 0.3 x 1.0 m spacing and coppiced after the 1983 growing season. The purpose of the test is to compare productivity between tree-form and shrub-form willow types. Conclusions should be possible after three cutting cycles.

Poplar Farming:

A two-year study of leaf protein and biomass productivity was established in 1982 at the Central Experimental Farm of Agriculture Canada in Ottawa. In cooperation with the University of Ottawa, 19 hybrid poplar clones were established from dormant cuttings in a replicated incomplete block design and grown for two years without coppicing.

In the autumn of 1984, prior to leaf-fall, an inventory was completed and the plantation was harvested and weighed. Except for the aspen clone A-10, survival exceeded 75% and mean height varied from 2.22 m (D-154) to 4.28 m (NM-1). Total above-ground productivity varied from 1.2 odt.ha^{-1} (D-154) to 14.2 odt.ha^{-1} (I-45/51). Foliage biomass ranged from 0 odt.ha^{-1} (D-154, leaves senesced prior to harvest) to 3.6 odt.ha^{-1} (NM-1). Final analyses of foliage chemistry will allow computation of protein productivity rates.

Energy Survey:

In 1981, the Ontario Ministry of Energy provided funds for two years (later extended to five years) to study hybrid poplar clonal energy productivity. A total of 133 clones comprised of one-year-old coppice sprouts were analysed for a variety of physical and chemical attributes including biomass productivity, stool characteristics, moisture content, mass energy density, energy productivity, specific gravity, lignin, extractive, bark, and pith content.

Large clonal variations have been found in most of these characteristics, and clones are being selected according to combinations of favourable properties such as high biomass productivity and high intrinsic energy content. The large number of clones and features allow clonal selection to be "customized" to a particular need, not only for energy conversion, but for uses such as fibre, fine chemicals, fermentation and food.

Regression analysis has suggested that bark, extractive, and lignin contents contribute significantly to variation in mass energy density.

The extractive content of selected clones was further analyzed by both batch and sequential polar-gradient solvent extraction. Energy loss due to extraction was best correlated with non-polar solvents (hexane). Further elaboration of these extracts using HPLC has indicated that at least two compounds were responsible for this effect. They have yet to be identified chemically.

Considerable variation also exists in the ash, sulphur and nutrient elements found in the bole tissue. Clones are therefore being selected for their low sulphur and ash contents and for efficient use of nutrients (i.e. high biomass production per unit nutrient uptake) in order to reduce pollution hazards during combustion, and nutrient drain due to intensive harvesting.

Studies of heritability of factors such as mass energy density and specific gravity, based on limited parent-offspring comparisons, indicate moderate levels of genetic control. When combined with the apparently high selection differential available in many characters, the possibility of significant genetic gain has led to some selective breeding trials, crossing a high-biomass female with high-energy males. Several hundred progeny in three families are currently being evaluated for combinations of these traits. Any promising individuals will be cloned for further study.

Other current work involves elaboration of the structural chemical components of the bole tissue (i.e. sugars) and additional extractives such as fatty acids to further account for variability in energy content and to explore possibilities of clonal selection for other energy conversion routes such as fermentation.

Final clonal selections will depend upon demonstrated productivity in field trials, established using techniques such as "scatter planting", and using strategies developed from clonal spacing/rotation studies.

(H.W. Anderson)

Breeding of Fast-Growing Hybrids

Poplar Breeding

The purpose of this research project is to develop fast-growing, pest-resistant varieties of poplar with desired biomass qualities. Work continued as outlined in earlier reports.

(L. Zsuffa)

Studies in Native Poplar Species

Initial results were obtained from the studies in native poplar species.

(L. Zsuffa)

Trembling Aspen

Dr. J. Hyun collected two hundred clones of trembling aspen (Populus tremuloides Michx.) along an east-west, north-south transect in Ontario. The clones were distributed throughout 21 stands in eight

geographic regions. Root tips were collected from young suckers of the clones and used in an isozyme study.

A total of 15 gene loci were resolved from eight different enzyme systems. The results indicated that most of the genetic variability resided within the population, and only 6.8% of the total genetic variability could be attributed to between-population differences.

(L. Zsuffa and J.O. Hyun)

Balsam Poplar

K. Falusi selected 40 female balsam poplar (Populus balsamifera L.) trees in an 80 km wide corridor extending from Lake Erie north to James Bay. Cuttings were taken from the mother tree, and open-pollinated seed was collected. The cuttings and the seed were rooted and germinated at Maple.

Twenty-nine half-sibs germinated in leach tubes in July were transferred to the greenhouse in January 1982. The seedlings were grown under a 12-hour and a 24-hour photoperiod. The experiment was terminated in May 1982.

At the conclusion of the experiment, under the 12-hour photoperiod, the tallest seedlings were from southern Ontario (Site region 7E) and averaged 15.7 cm in height. The shortest seedlings were from northern Ontario (Site region 2E) averaging 2.3 cm. Under 24-hour light, the seedlings from both northern and southern Ontario showed no significant difference in growth rate, or in final height, which averaged 52.7 cm.

The seedlings were outplanted in the nursery at Maple where observations are continuing.

(L. Zsuffa and K. Falusi)

Poplar Hybridization

In 1981, and again in 1982, the following crosses were made by O.P. Rajora:

	Number of Combinations
P. deltoides x deltoides	4
P. deltoides x nigra	4
P. deltoides x maximowiczii	4

Twenty-eight pollen mix crosses were made using P. deltoides, P. nigra, and P. maximowiczii in all combinations of two's, using P. deltoides as the female parent. These crosses provided information on the species "preference" in pollination.

The inheritance of 12 isozyme systems were studied. They were found to inherit codominantly according to Mendelian patterns. The use of isozymes as genetic markers distinguished the interspecific hybrids produced from these three Populus species.

The full-sibs produced through controlled pollination are planted in the nursery at Maple in a replicated trial. This trial will provide information on heritability of growth parameters, leaf characteristics, and combining ability.

(L. Zsuffa and O.P. Rajora)

Poplar Trials

In northern Ontario nurseries, frost hardiness trials were expanded. At Kapuskasing (northern Ontario), an aspen range test, several progeny trials, and a clonal test were established. These experiments were replicated in southern Ontario (Midhurst).

In southeastern Ontario (Brockville), a series of five clonal trials were established, as well as progeny trials of P. deltoides and interspecific hybrids.

At several locations across southern Ontario (Cornwall, Cambridge, Lindsay, Owen Sound, and Maple), clonal trials were established. Finally, at Dryden, in northwestern Ontario, a poplar hybrid progeny trial was established.

(L. Zsuffa and D. Boufford)

Willow Collection and Hybridization

Salix species are noted for their rapid growth rate, their ease of propagation, and their ability to survive high moisture levels. These characteristics make willow attractive to breeders interested in growing biomass for energy production. Salix species are also adapted to a variety of other end uses. As little is known about our native Salix species, collections of native species and the identification of the same were carried out at Maple to facilitate the basic selection requirements for this species.

During the spring of 1983, a hybridization program was established by A. Mosseler to determine the crossability patterns and characteristics of interspecific hybrids. Of the 50 hybrids produced, the early results indicate successful crosses between Salix exigua x eriocephala, S. petiolaris x eriocephyla, S. bebbiana x eriocephala, S. pellita x discolor, S. lucida x exigua, and S. petiolaris x exigua.

(L. Zsuffa and A. Mosseler)

Alder and Birch Hybridization

Alder and birch, in addition to poplar and willow, are important for short rotation intensively managed "biomass" plantation systems.

Interspecific hybridization experiments in the genera Alnus and Betula were initiated by S. Hoover, J. Russell and K. Falusi. Speckled alder (Alnus rugosa (Du Roi)) and European alder (A. glutinosa (L.) Gaertn.) were crossed with each other as well as with green alder (A. crispa (Ait.) Pursh.) and red alder (A. rubra Bong.). Conelets were formed in all crosses except A. rugosa x glutinosa. Average take of the female flowers varied from 11% to 69% among the crosses.

All possible combinations involving white birch (Betula papyrifera Marsh.), yellow birch (B. alleghaniensis Britton), and European birch (B. verrucosa Ehrh.) were crossed. Fruit developed in B. papyrifera x papyrifera, B. papyrifera x alleghaniensis, B. verrucosa x papyrifera, and B. verrucosa x alleghaniensis. Average take of the female flowers varied from 25% to 63%.

(L. Zsuffa, S. Hoover, J. Russell and K. Falusi)

Introduction of New Species and Clones

The purpose of this research project is to create intensive plantations of species and clones of demonstrated value for uses such as: veneer and pulp (poplar); effluent disposal (poplar, willow and sycamore); and energy (willow and paulownia). Material obtained to date from centres of recognized excellence in tree breeding (USA, West Germany, Italy, France, Belgium, Holland, Austria, Spain, Hungary, Bulgaria, Czechoslovakia and People's Republic of China) consists of 115 poplar clones, 14 willow tree clones of Salix alba, 24 clones of provenances of sycamore (Platanus occidentalis and P. x acerifolia), and eight provenances of Paulownia tomentosa.

The poplars and willows have been added to the existing clonal collection at OTIFBI, while the sycamore collection has been planted at the Maple Woodlot managed in co-operation with the University of Toronto. Some of the Salix alba clones have also been used in experimental plantations for effluent disposal at Seneca College in King City. Regular observations of the phenological characteristics of this new material are planned to assess its suitability to Ontario's various climates. The incidence of abiotic damages and the occurrence of quarantine pathogens will also be monitored.

The preliminary phase of this research yielded several findings, briefly enumerated below. (1) Several of the newly imported poplar clones present some traits of outstanding importance for effluent recycling through intensive silviculture, such as: immunity to foliar pathogens; increased tolerance for high concentration of organic/inorganic nitrogen in the soil; high foliar nitrogen content (6% and over); horizontal position of leaves and rigid stem attachment which inhibit the runoff of sprayed effluent and enhance disposal into the atmosphere through direct evaporation; and ability to maintain foliage in a functional condition up to the winter frost. (2) Poplars and willows produce a large volume of foliage, and biomass production for energy entails rapid turnover; this combination may prove an effective means of soil decontamination. (3) Successful, large-scale propagation of sycamore cuttings is possible. (4) Although the paulownia seedlings show an impressive growth potential in Ontario, this species suffers regular frost damage and can be considered only for cultures harvested yearly. With yearly harvesting, for the conditions of southwestern Ontario, the total biomass production of paulownia may equal those of poplar and willow, thus enlarging the range of agriculturally marginal sites on which such silviculture may be practised.

(C. Papadopol)

Larch

Stand Location, Mapping and Assessment

The purpose of this project is to locate, map and assess natural stands of tamarack that may be used for the selection of superior individuals and the collection of breeding materials. The information collected is being used to assess the variation in various traits and to determine the criteria for superior tree selection. The Algonquin, Central and Eastern Regions have been completed, and the Northeastern Region is currently being studied.

(L. Farintosh)

Clone Bank at OTIFBI

A tamarack clone bank was established at OTIFBI for future breeding work. Ten ramets of each of 30 clones, collected from phenotypically superior trees in the Algonquin Region, were planted in the spring of 1985. This material will be used to develop pollen handling and pollination techniques as well as for other breeding work.

(L. Farintosh)

Genetic Architecture Study:
Rooted Cuttings Trial

The objective of this study is to provide information on the distribution of genetic variation of tamarack and on the heritability of growth and form characteristics. In addition, the performance of tamarack rooted cuttings will be observed and evaluated.

Cuttings were taken from donor plants grown from seed collected across site region 4S and rooted in fir Leach tubes. About 10 000 cuttings were outplanted in the spring of 1985 in Dryden District. The experiment was replicated six times with 20 families/replication, four clones/family and four ramets/clone.

A similar study was established by the Nipigon District staff in cooperation with Domtar Inc. Approximately 9 500 rooted cuttings from site regions 3W and 4W were planted.

E.B. Eddy Forest Products Ltd. also planted some tamarack rooted cuttings in the spring of 1985. About 6 000 trees were planted near Espanola and 2 000 in Timmins District.

(L. Farintosh)

Annotated Bibliography

An annotated bibiography of the genus Larix, as related to tree improvement and genetics, is being compiled.

(L. Farintosh)

Spruce

Spruce Hybridization

1982/83:

Attention continues to be given to interspecific breeding in black spruce in order to improve growth and adaptability of this species in the boreal forest. Black spruce remains stubbornly incompatible with many other spruce species, yet we do have a few promising hybrids. We have established hybrid progeny trials of the well-known black x Serbian spruce (Picea mariana x P. omorika) and reciprocals in the Sault Ste. Marie and Swastika Districts. Small numbers of Sitka x black spruce (P. sitchensis x P. mariana) crosses have been produced over the past few years and we expect to clone them for testing.

White spruce is also receiving attention. Heretofore, most white x Sitka spruce (P. glauca x P. stichensis) combinations have been

attractive because the species are entirely compatible and the hybrids exceedingly easy to produce. The hybrid progeny however have been disappointing in that they have generally been the product of random interspecific crossing and have not proven to be in any useful way superior to the parent species (cf. Hood, Forest Research 1981-1982, p.9). Even so, among these progeny there is always the chance for some individual superiority and hence selection advantage for tree improvement. However, in the crossing program under way, attention is directed towards specific selections, particularly with respect to latitude. A number of crosses in the design have already been made and the seed placed in storage. The program entails substantial white spruce pollen collections at various latitudes in Ontario, during flowering.

Al Gordon has been hybridizing species of spruce to improve growth and yield.

In 1982, flowering in spruce was moderate and widespread, facilitating both pollen collection and breeding. Three latitudinally separated breeding areas were utilized: Sault Ste. Marie, Algonquin and Simcoe Districts. Including the aforementioned black and white spruce, 214 tree x pollen combinations were attempted involving 63 interspecific crosses, ten tri-hybrid crosses and 16 species. Some of these were repeat crosses to establish reproducibility or to build up hybrid stocks for cloning and testing. A considerable number were failures. One new-to-science cross, P. mexicana x P. omorika, was produced and confirmed. Progeny from this cross have favourable growth characteristics. There were a few other new crosses, but these have not yet been confirmed.

Progeny testing of hybrid seedling and clonal stock is increasingly important. One single-species, family-source hybrid experiment was

field planted, as well as two trials of additional crosses of the rapidly growing P. omorika x P. rubens hybrids. These will also be used for further selection. One test of our new P. stichensis x P. rubens hybrids was also established. These seedlings are very promising and are currently being cloned for testing in other environments.

Cloning of a substantial number of difficult-to-make hybrids, as well as the direct use of hybrid seedlings where numbers are sufficient for testing in different sites and site regions, is a major activity.

First plantation measurements were completed for the Piceta in Swastika, Geraldton and Kenora. This will enable us to commence productivity calculations for comparisons and for subsequent selection of these phenotypes and genotypes.

1983/84:

When spruce flowering years are moderate to good, as well as widespread, i.e. in all site regions, we are able to carry on breeding work at three different latitudes (site regions), and pollen collections extending even further. When flowering years are poor to fair and not widespread, breeding is restricted to the Piceta which are most stressed, usually in the extreme southern part of the province.

Flowering in 1983 was moderate and we were again able to use three widely separated breeding areas: Sault Ste. Marie, Algonquin and Simcoe Districts. A total of 266 tree x pollen parent combinations were made, utilizing 365 ramets. Interspecific crosses totalled 36, tri-hybrid crosses four, and hybrid backcrosses two. Tri-hybrid and hybrid backcrossing involved four species, and interspecific crossing 19 species.

Emphasis was continued on boreal black spruce. Most of these crosses were failures; however, one source from Thunder Bay was crossed successfully with P. engelmannii and a few from Moosonee were successful with P. sitchensis. Crossability is low, but some of the hybrids, including that of P. mariana (black spruce) x P. engelmannii (Engelmann spruce), are strongly heterotic and grow much faster than the P. mariana x P. mariana (black spruce) controls. They indicate good potential for tree improvement and are being cloned for testing.

Other new crosses were P. mexicana x P. mariana, a very difficult cross, and P. omorika x P. farreri. Crossability was moderate. The latter species is an isolated high-elevation Burmese species related to P. spinulosa. Its exact specific status is not yet confirmed. Repeatability crosses were obtained with new selections of P. rubens x P. sitchensis, P. rubens x P. maximowiczii, and P. omorika x P. maximowiczii.

Tri-hybrid and hybrid backcrossing in 1983 involved attempts to increase variation and to detect what its pattern might be. Since P. mariana may be crossed with P. rubens and crosses with great ease with P. omorika, it was assumed there would be no barriers to crossing it with our P. omorika x P. rubens and reciprocal hybrids. However, there have indeed proven to be substantial differences in variation in both crossability and growth rates between families. Some hybrids will not accept P. mariana pollen while others accept it freely. No hybrid would accept P. breweriana pollen.

A progeny trial of black spruce families was established in Algonquin District, and of white and Engelmann families at Batchawana, Sault Ste. Marie District.

1984/85:

1984 was a magnificent spruce flowering year in Ontario and in fact across the country. We carried out our largest crossing to date. A total of 498 tree x pollen parent combinations were attempted with many more ramets. There were 126 interspecific crosses, four tri-hybrid crosses and three hybrid backcrosses. Tri-hybrid and hybrid backcrossing involved seven species, and interspecific crossing 18 species.

Small numbers of seedlings were obtained from crosses of high-latitude selections of P. sitchensis crossed with northern P. mariana, and many more from the much easier crosses with boreal forest P. glauca. P. rubens was also crossed successfully with northern selections of P. sitchensis.

Successful crosses not previously reported were P. glauca x P. likiangensis. The results were very consistent between parents, and hybridity of the seedlings has been confirmed. Results for the new cross, P. orientalis x P. maximowiczii, were similar. This latter cross is interesting. Both species, one from northern Turkey and the other from Japan, are rather reluctant crossers with a small number of other species, but the crossability between them is extraordinarily high.

Another possible new cross is P. orientalis x P. farreri. This has not been confirmed as yet. A number of crosses in the P. abies x P. asperata group were successful as expected, but there is little yet to report on them.

Successful 'repeatability' crosses confirmed again the low crossabilities of P. orientalis x P. rubens; and P. mexicana x P. omorika, x P. engelmannii and x P. mariana. (The latter is only the second time we have accomplished this cross.) Repeatability crosses also confirmed the moderately high crossabilities of P. mexicana x P. rubens and x P. sitchensis.

The nature of the new cross of P. mexicana x P. mariana in 1983 and 1984 provides further evidence of the genetic separation between P. mariana and P. rubens. In contrast to the crossing behaviour of P. mexicana with P. mariana, P. mexicana crosses freely with, and exhibits little evidence of any crossing barriers against, P. rubens. The first crosses of P. mexicana and P. rubens were achieved in 1978, and were easily repeated with other selections in 1980 and in 1984. This contributes further to the contradictory evidence that selections of species from widely separated populations or from where the species ranges do not overlap are amenable to low-level crossing.

It also is interesting to note that P. omorika, which crosses relatively easily with both P. rubens and P. mariana, crosses only very reluctantly with P. mexicana. Similarly, P. likiangensis crosses freely with P. omorika; very well with P. rubens; moderately, with P. mexicana; sparingly with P. glauca; and thus far not at all with P. mariana. We crossed P. mariana with P. likiangensis extensively in both 1983 and 1984, all without success.

Finally, in tri-hybrid crossing and hybrid backcrossing in 1984, P. x lutzii (P. sitchensis x P. glauca) was backcrossed successfully with P. sitchensis and out-crossed with P. rubens. P. glauca x P. mariana (Rosendahl spruce) open-pollinated progeny were successfully backcrossed with both P. mariana and P. glauca, as well as out-crossed with P. rubens. Some of these progeny share morphological characters of P. glauca, some with P. mariana, and others are intermediate. All, however, share exactly similar physiological attributes. It has been suggested that Rosendahl spruce is simply a white spruce. Evidence here suggests otherwise. Some individual progeny, whether white-like or black-like, successfully accept pollen from both white or black spruce, and also red, far in excess of what control white or black spruce will accept.

(A.G. Gordon)

Outplanting of Clonal Interspecific Hybrids

Several thousand clonal stock from 35 selections of our remarkably heterotic hybrid P. omorika x P. rubens were outplanted in the spring of 1983 in the Parry Sound District. They were 10-15 cm (4-6 in.) in height at planting and quite spindly. An intense and widespread early summer drought in 1983 (probably accounting for the widespread seed year in spruce in 1984) killed many of these clonal stock. The survivors, about 68% in 1984, have however grown remarkably well, considering their difficult start. Many exceed 60 cm (2 ft.) in height at the end of their third year, 1985.

(A.G. Gordon)

Norway Spruce

Breeding Orchard

A tree improvement program was initiated for Norway spruce to produce improved stock for artificial regeneration. Norway spruce plantations were located and assessed for site characteristics, growth, and quality. Sixty candidate trees were selected based on growth, stem form, crown form, and branch characteristics. An additional 104 clones were selected from existing clone banks at OTIFBI and PNFI. Scions were collected from each of these and grafted, and will be planted in a breeding orchard in 1987. When this breeding orchard flowers, controlled crosses will be carried out according to a planned mating design. The resulting seed will be used to grow donor plants for vegetative propagation by rooted cuttings. These will be planted in field tests and production plantations. The field tests will identify the best families, which will be recreated and vegetatively propagated for use in the artificial regeneration program.

(J. Wild)

Genetic Test

A genetic test was initiated in 1984, which was an exceptional year for flower production, and thus provided a rare opportunity to carry out a large breeding program. Two hundred and fifty families were created for this test using 48 parental clones. The test is divided into three parts, each with its own purpose. The first part is a progeny test of

18 clones in the Norway spruce breeding orchard. A disconnected partial diallel mating design was used to create 89 families from the 18 clones. These families will be planted as a progeny test to estimate general and specific combining ability of the parental clones. The best families will be identified, recreated and propagated by rooted cuttings for use in regeneration programs.

The second part of the genetic test is a hybrid test. Ninety-seven hybrid crosses and backcrosses were done involving Picea abies, P. koyamai, P. asperata, P. abies x P. montigena, P. abies x P. koyamai, P. montigena x P. asperata, P. montigena x P. koyamai, and P. asperata x P. abies. These families will be grown to observe their performance and identify promising additional sources of genetic variation for future breeding work.

The third part of the genetic test consists of bulk seed collected from white and Norway spruce stands across southern Ontario. The object is to demonstrate growth differences between these species. The consensus is that Norway spruce outperforms white spruce; however, this has never been clearly shown. In addition, this test will evaluate stands for designation as seed production and collection areas.

(J. Wild)

Annotated Bibliography

An extensive annotated bibliography on genetics and tree improvement of Norway spruce was prepared.

(J. Wild)

White Pine

White Pine Hybridization

In order to incorporate new genes into the white pine blister-rust-resistant population, the crossability patterns of different white pine species were determined. The controlled crosses included P. strobus x monticola, P. strobus x lambertiana, P. strobus x peuce, P. strobus x koriensis, and P. strobus x albicaulis. These crosses were repeated using P. griffithii, P. monticola, and P. monticola x peuce as the female parent.

In 1983 the emphasis was placed on reproducing hybrid white pine which showed resistance to blister rust. An experiment was designed to determine the advantages of a syringe vs an aspirator in pollen application. The crosses made included P. strobus x griffithii, P. strobus x peuce, and P. strobus x strobus. The crosses were repeated using P. griffithii and P. peuce as the female parent.

(L. Zsuffa)

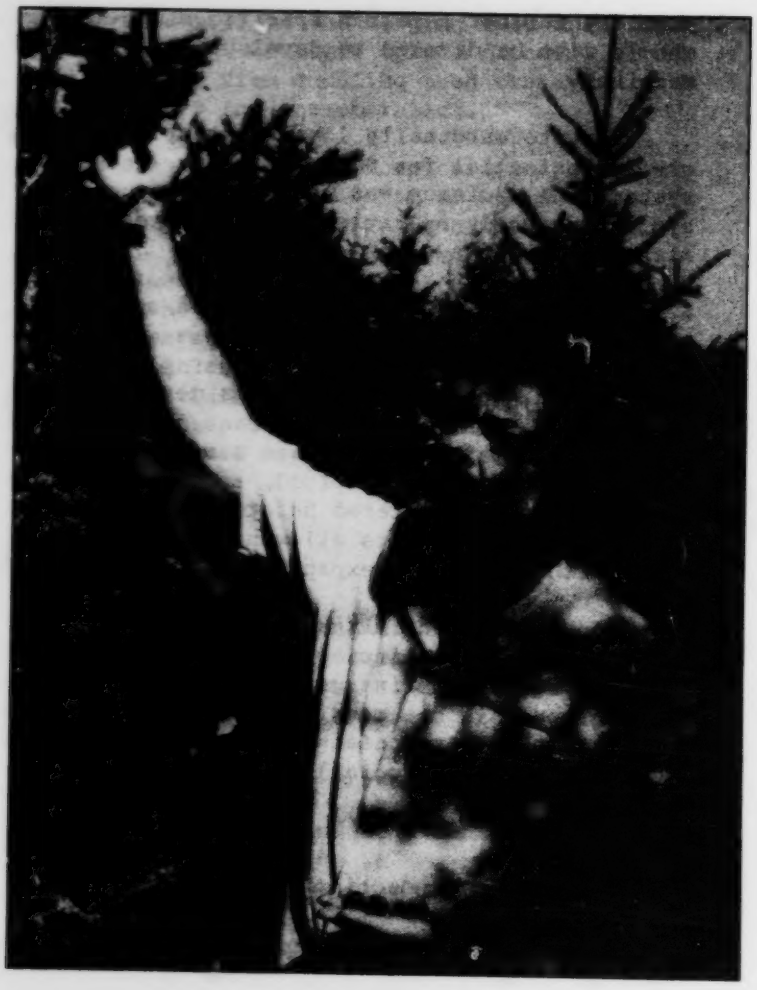
Progeny Trials

Five progeny trials were established. The trials were located in the districts of Blind River, Bracebridge, Cambridge, Cornwall, and Owen Sound. Included in these trials were open-pollinated progenies of P. strobus plus tree selections, and full-sibs of interspecific hybrids. To alleviate weevil problems in two trials, white pine progenies were interplanted with poplar clonal material.

(L. Zsuffa and D. Boufford)

Accelerated Transplants

An economic study of transplant systems was completed in 1982. (Ernt and Whinney. 1982. Preliminary guidelines for the development of black spruce accelerated transplant systems.) The study was commissioned by Forest Resources Branch to evaluate production costs for a variety of systems developed or adapted by provincial nurseries and by research scientists at Maple.



Doug Skeates is working on techniques for collecting, storing and planting high-quality tree seed which could increase production of transplant stock without expansion of nursery facilities.

Based on data and operations descriptions, detailed analyses were conducted on each of the following systems:

Paperpot
Spencer Lamaire
Dryden cigarettes
Dewa peat cube
Accelerated transplant bare root
Mini plug (Blackmore)
Micro plug double transplant
Micro plug, direct transplant

The most significant cost factors were related to plant density in the greenhouse and cost of containers. High-density micro plugs planted directly into the nursery at $67/M total production cost were the most cost-effective, if the goal of a two-year transplant can be achieved. The peat cube developed at OTIFBI was the most cost-effective 'conventional'-sized container transplant, being only approximately $5/M more expensive than bare-root accelerated transplants (100/M). Other containers with an actual container material cost ranged up to $122/M.

The consultants recommended development of biologically feasible high-density container systems that would facilitate mechanical singulation of seedlings. Specifically, it was recommended that the Ministry further research specific micro- and mini-plug systems. Funds should also be devoted to development and/or testing of transplanting machines.

Despite marginally lower costs for the A.T.P. bare-root systems, greater potential for reducing costs was seen for non-bare-root systems. A decision was made to continue with the bare-root greenhouse system currently operational while investigating high-density mini- and micro-container systems.

Studies initiated at Maple have continued there to evaluate the potential of high-density greenhouse systems planted directly into the nursery. Systems include Wiesinger plugs, 3/8" cigarettes and composition 'Techniculture' plugs developed by Castle and Cook. Studies also include similar systems planted into containers as a 'two transplant' system. These are summer-sown and grown in greenhouses when no heating costs are involved, summer-transplanted into containers outside, and overwintered before spring transplanting. The goal would be one-year transplants allowing increased production of transplant stock without nursery expansion.

Of equal potential value is the use of high-density greenhouse production for container planting. Plants are initiated at 1 000 or more per sq. ft. during germination and early plant development, when growing space is not required. Container stock can then be grown outdoors in larger containers where space is not a major cost item, but is an important biological consideration in the growing of vigorous planting stock.

(D.A. Skeates)

Coniferous Seed Production

A program of monitoring seed production in registered stands continued through the 1984/85 season. A heavy seed production year in white spruce allowed completion of one major project, and contributed valuable information on others. Establishment of normal standards of production provides a basis for future studies of management techniques to increase yield and quality.

Collections relate to four major black spruce projects. The first was a three-year study of yields from natural upland stands in Sioux Lookout, Geraldton, Hearst and Cochrane. Factors included stand age and stocking. A second was a study of seed yield and quality related to cone size in Nipigon, Geraldton, Kapuskasing, Sioux Lookout, Ignace and Red Lake. The third is an ongoing study monitoring seed yield and

quality in permanent seed sources in Nipigon, Kapuskasing, Geraldton and the Kimberly Clark seed orchard at Longlac. Finally, data has been compiled from the gene pool collections of Northwestern Region.

Two white spruce studies continued through 1984/85. The major work in a study of cone and seed yield and quality on an individual tree basis in the Orono seed production area was completed in 1984. Collections had been made since 1971. Monitoring of cone and seed yields continued in stands and plantations in Nipigon, Kapuskasing, Kirkland Lake and the Longlac Seed Orchard.

Emphasis in the future will be placed on production factors in seed orchards. The principal study area will be the Longlac seed orchards where studies were initiated in 1982. The black spruce orchard, though clonal, will be used to simulate data from seedling seed orchards, with collections from natural stands added for corroboration.

One difficulty associated with collection of cones from permanent sources, particularly for black spruce, is access to crowns of taller trees. A pilot collection was completed in conjunction with scientists in the Canadian Forestry Service. A portable cone tower developed at Maple in the early 1970s was evaluated in a 20 m tall seed production area in the Geraldton district. The tower was found to be an effective tool for reaching the tops of black spruce crowns. Using a J-5 for motive power and moving the tower in an upright position, the equipment appeared to have considerable potential for cone collection. Up to 12 tops were collected from a single setup by pulling crowns into the deck. Modifications were recommended to improve the effectiveness of the tower.

(D.A. Skeates)

White Spruce Growth Related to Seed Origin

A cooperative project of white spruce plantation performance related to seed origin was continued. One experiment was established by the Petawawa National Forest Institute at Red Lake, and two in southern Ontario, Owen Sound and Cornwall were planted by crews from Maple.

The Red Lake experiment was a replacement for an earlier study burned out in the heavy fire season of 1980. Owen Sound is an all-range study with 30 sources from across the range and 50 Ontario sources. The other two were regional studies with 80 sources in each from across Ontario.

The final experiments in this project were started. The first, a Site 3E regional, 80-source trial intended for Kirkland Lake District, was transplanted into Swastika nursery. The second, incorporating most of the sources, is being grown at Petawawa for establishment at the Petawawa National Forest Institute.

The earliest plantings of the first series of experiments in northwestern and north central Ontario were assessed. Establishment difficulties were experienced with heavy grass competition on an agricultural site in Fort Francis, though fifth-year survival was very high. The Kenora experiment exhibited similar survival and exceptional early growth. Data has indicated correlations between nursery performance and outplanting growth, a factor of some concern in analysing seed source experiments grown in nurseries far removed from

planting sites. Obviously unsuitable sources such as Birch Island, B.C., the fastest-growing source in Dryden nursery, changed ranking dramatically when outplanted.

(D.A. Skeates)

White Spruce Gene Pool

A project to identify residual sources of white spruce in southern Ontario has been completed. Regional reports had been previously prepared for the districts of Central and Southwestern Regions, and Pembroke of the Algonquin Region. The 1982/83 survey of Eastern Region completed the picture. The regional report was presented to Tweed, Napanee, Brockville, Cornwall and Carleton Place Districts on completion.

Seed collections were made in some of the stands identified earlier in the Southwestern and Central Regions. These were primarily for the purpose of studying seed and genetic viability. However, they also serve conservation purposes through ex-situ storage of seed and eventual district plantations of these specific pools.

(D.A. Skeates)

STOCK PRODUCTION

Container Seedling Production

Hardening Regimes for Overwintering Spruce Container Seedlings

The investigation of factors influencing the development of winter hardiness has accounted for much of the container-stock-related research at OTIFBI. A great deal of the developmental work has been done in cooperation with Richard Cameron, Assistant Superintendent of the Swastika Tree Nursery, and Brian Polhill, Nursery Forester at the Dryden Tree Nursery.

Severe overwinter damage to spruce container seedlings grown in greenhouses prompted the development of a new hardening regime: Extended Greenhouse Culture which has been used operationally since 1983 to prepare more than 30 million spruce seedlings for overwintering.

Hardening trials have been conducted annually since 1982 to examine the winter hardening process in black spruce container seedlings given different treatments. In 1982, the following trial was conducted. Along with one treatment representing the previously unsuccessful hardening regime used in Ontario prior to 1983 (seedlings moved outside in August while still actively growing in height, following a two-week period without nitrogen fertilization), three variations of Extended Greenhouse Culture were tested: i) Seedlings kept in a greenhouse at natural daylengths without fertilization; ii) as in i) but with fertilization using Plant Products 20.20.20 (N.P.K) fertilizer at 200 ppm N applied during hardening; and iii) seedlings induced to set bud using an artificial short (8 h) day treatment. Height growth, bud development and frost hardiness were assessed weekly from August 17 to November 23, 1982.

Height growth stopped soonest in short-day seedlings. Buds were initiated at the same time in all treatments (initiation was greater than 50% when treatments began), but there were large differences in the final numbers of needle primordia in the buds. Production-run seedlings formed the smallest buds, with an average of only 140 needle primordia final numbers of needle primordia in the buds. Production-run seedlings on November 23. Short-day seedlings averaged 157 primordia on the same date. In comparison, seedlings kept in a greenhouse at natural day-lengths with or without fertilization had respectively on average 225 and 249 needle primordia. Frost hardiness reached high levels by October 5 in short-day trees; all other treatments reached high levels of frost hardiness within the next three weeks.

At the same time as this experiment was being performed, Extended Greenhouse Culture was being used operationally on a large scale (approximately five million seedlings) in the Provincial Tree Nurseries at Swastika, Thunder Bay and Dryden. The beneficial influence of Extended Greenhouse Culture was evident in Dryden, where about 50 000 seedlings moved outside on September 7 suffered almost 100% winter kill, while extended greenhouse seedlings moved outside October 14 suffered only 5% overwinter mortality. Similar research trials with associated nursery testing have been conducted annually.

(S. Colombo)

Regional Testing Laboratories

The operational use of Extended Greenhouse Culture requires close monitoring of frost hardiness and bud development as winter hardiness develops. To meet this need, the Northern and Northwestern Regions have established laboratories at their respective OMNR regional nurseries to monitor container seedlings from both private and OMNR nurseries. Staff for these laboratories were trained at OTIFBI. In addition, operational testing has been conducted for the North Central Region at OTIFBI, with regional support. A manual describing laboratory operation and establishment for performing frost hardiness tests has been published (OMNR Research Report No. 110). Similar testing laboratories are also being established independently in Alberta, Manitoba and New Brunswick.

In cooperation with the Northwestern Region and the Dryden Tree Nursery, we have developed a new, short test technique for assessing freezing tests. This technique shortens test duration from 72 hours to 24 hours, and when implemented will help container-stock growers to move seedlings outside on the earliest possible dates. This improvement in test procedures should increase the likelihood of successful over-wintering.

(S. Colombo)

Field Performance of Extended Greenhouse Stock

Experimental plantations have been established since 1982 to examine the field performance of extended greenhouse black spruce and/or jack pine seedlings in comparison with the previous production-run stock. In 1982, plantations were located at the Swastika Tree Nursery under partially controlled conditions and near Montreal River Harbour under operational conditions. During 1983-1986, test plantings were also established at the Midhurst Research Station to examine the effects of hardening regimes on subsequent field performance.

(S. Colombo)

Bud Development in Black Spruce Container Seedlings

Bud development is one aspect of seedling quality which can be greatly improved by nursery practice and which can improve outplanting performance. Therefore, the level of bud development in 1982/83 overwintered black spruce container seedlings throughout the province was determined and results published in OTIFBI Research Note No. 38. Using this information, future improvements in bud development can be evaluated.

Steve Colombo

In 1982, the provincial average for bud development in black spruce container stock from OMNR nurseries was 136 needle primordia. By region, the averages were 164 in the Northern, 158 in the North Central, and 102 needle primordia in buds of Northwestern Region trees. Differences in bud development were attributable primarily to nursery cultural practices, while seedlot differences within each nursery were negligible. The upper limit of bud development is not yet known, but large-diameter first-year spruce seedlings may be able to form buds with more than 350 needle primordia. Provincial averages of bud development are being assessed for the 1983/84, 1984/85 and 1985/86 overwintered spruce container seedling crops.

(S. Colombo)

Extended Greenhouse Culture for Jack Pine

In 1985, recommendations for Extended Greenhouse Culture of jack pine were issued. These recommendations were based upon trials conducted annually since 1981/82 and on operational testing at the Dryden Tree Nursery. In 1984/85, the effects of fertilization rate on hardening jack pine seedlings were assessed. Seedlings were fertilized following bud initiation at rates of 35, 150 or 350 ppm N (using a 20.20.20 fertilizer). In addition, there was a non-fertilized control. Fertilization rate did not delay frost hardiness development, but fertilized seedlings had significantly greater dry weight and diameter at the end of the hardening period. Amino acids in seedlings from this trial were assessed by Y.T. Kim and C. Glerum who determined that the concentrations of most amino acids increased with fertilization rate. Seedlings from each treatment were sampled also during the hardening period to assess water relations (cell osmotic potentials and elasticity).

(S. Colombo)

Nursery Stock Stress Resistance

The exposure of tree seedlings to stresses such as drought, heat and frost following planting is a major factor affecting plantation establishment. Methods of i) determining stress resistance and ii) increasing stress resistance of nursery stock are therefore greatly needed. In 1983/84 a program was initiated to address problems in nursery stock stress resistance.

Plant Moisture Stress

The pressure chamber is a portable field instrument which can give a rapid evaluation of the moisture status of tree seedlings. However, this technique is not as widely used by nursery and field staff as it should be, principally because no criteria exist by which critical levels of plant moisture stress can be judged. Therefore, we are developing an operational procedure based upon the pressure-volume curve technique by which the "wilting point" of nursery stock lots can be determined. The wilting point is important with respect to the ability of tree seedlings to photosynthesize and grow. If the wilting point is determined at the time seedlings are lifted for shipping, such information could be included with the shipping records to indicate maximum levels of acceptable moisture stress measured at the planting site.

(S. Colombo)

Root Growth Capacity

Drought can be avoided or reduced if seedlings rapidly produce large quantities of new, moisture-absorbing roots after planting. Seedlings with very low levels of root growth capacity (RGC) are of low quality with limited chance of rapid growth even if survival after planting is adequate. The goal of our studies of root growth capacity is to develop an operational testing program. Seedlings identified as having little or no root growth capacity would be better culled than planted. Seedlings with moderate levels of RGC could be planted on less drought-prone sites or be planted at a greater density to compensate for potential reductions in survival. We are investigating: i) differences in moisture absorbing capacity of seedlings with different root growth patterns (eg. seedlings which produce just a few long white roots versus those with many short white roots); ii) the field conditions under which low levels of root growth capacity become limiting; iii) the relationships between root growth capacity and plant moisture stress as measured using the pressure chamber; and iv) the relationship between root growth capacity and hydraulic conductivity.

(S. Colombo)

Antitranspirants

Antitranspirants are usually wax or petroleum-based products which, when sprayed on tree seedlings, act as a physical barrier to moisture loss. The potential benefits to forestry of an effective antitranspirant are great. We are therefore conducting screening trials of a number of commercially available antitranspirants to determine which products meet our criteria of effectiveness without phytotoxicity. Acceptable products from our screening trials are being tested for their potential

in preventing winter-drying in nursery beds where adequate snow cover is lacking, and as a means of slowing transpiration to prevent drought following field planting.

(S. Colombo)

Preconditioning Nursery Stock for Stress Tolerance

In addition to avoiding drought conditions i) by planting seedlings which have high levels of root growth or ii) by reducing transpiration using foliage sprays, we are investigating means of increasing seedling ability to tolerate drought. In 1985, outplantings (black spruce container seedlings) were established on a sandy site at the Midhurst Research Station in July and August. Survival at the end of the first growing season in the second of three sequential plantings was 70% for the actively growing control treatment, but 93% of the seedlings which had initiated buds two weeks previously in response to short-day treatment at the end of the greenhouse culture period survived. Bud initiation and other treatments such as ion loading will continue to be investigated as means of increasing drought tolerance of black spruce and jack pine container seedlings.

(S. Colombo)

Physiology

Dormancy and Frost Hardiness

To determine the state of dormancy in nursery stock is important because the best time for moving stock for overwinter storage and/or for outplanting is when the stock is fully dormant. This increases survival and subsequent growth after outplanting. Therefore, we need the ability to determine dormancy. Two approaches are being tested: one is physical and the other is chemical.

Physical Techniques:

The physical approach involves electrical impedance, degree-days, degree-hardening-days and square wave oscilloscope traces. Seedlings are lifted at regular intervals (usually weekly) during the fall, then placed in overwinter frozen storage and outplanted the following spring. The results so far indicate that the transition from unsafe lifting to safe lifting is abrupt and occurs somewhere around mid- to late October for the Midhurst area. There are indications that very late fall lifting might be detrimental.

The impedance technique for determining readiness for lifting is considerably more reliable than the other techniques. Consequently, those techniques were not tested further. It is planned to establish electrical impedance safe-lifting zones in the fall of 1985 and 1986 at all nurseries.

(G. Racey, C. Glerum and R. Hutchison)

Chemical Techniques:

The chemical technique involves monitoring the seasonal patterns of amino acids within the seedlings. Standardized extraction procedures

are now used to extract amino acids from freeze-dried needles and root tissue. The amino acids are separated two-dimensionally on thin-layer chromatographic plates (TLC). Micro-crystalline cellulose is used on the TLC plates. So far 17 amino acids have been identified: alanine, arginine, aspartic acid, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, phenylalanine, proline, serine, threonine, tryptophane, tyrosine, valine and γ-amino-n-butylic acid.

The amino acid patterns for all conifer species tested (red, white and jack pine, and white and black spruce) appear to be similar except for variations in concentrations. The method to determine amino acid concentrations was developed in 1983 and involves measuring the area occupied by the spotted amino acids. We are now able to identify 20 amino acids, of which 16 can be quantitated. The amino acid tryptophane exhibits a distinct seasonal trend, and appears at present to be the most promising amino acid for our purposes (i.e., indicator compound).

(Y.T. Kim and C. Glerum)

Chris Glerum

Production and Performance of Coniferous Planting Stock

Container Stock vs. Bare-Root Stock

In the spring of 1979, some jack pine overwintered in Japanese paper pots and Spencer-Lemaire containers were outplanted with bare-root stock in the Wawa district on moist and on dry sites. The purpose of

the planting was to test the container stock and determine to what extent site differences influence survival and subsequent growth. To extend the planting season, the plantings were spread out over a month by having three plantings which were two weeks apart. Some spring-sown stock was also planted.

Both container and bare-root stock were cold-stored (±1°C) between the plantings. First-year results suggest that bare-root stock is better able to withstand the cold storage than the container stock.

After five growing seasons in the field, the survival of the overwintered paperpot and Spencer-Lemaire stock was significantly better than the bare-root stock. Height differences, which were significant at time of planting, were no longer significant by the third year on the fresher site, and by the fourth year on the drier site. There were no significant differences in survival between the overwintered paperpot and the spring-sown paperpot. The total height after five growing seasons of the spring-sown paperpot was equivalent to the total height of the overwintered paperpot after four growing seasons.

(C. Glerum and J. Paterson)

Irregular Growth of Outplanted Red Pine

This study was started in 1976 and has demonstrated that handling and planting are two factors that can detrimentally influence outplanting performance. The 1978 red pine stock types 3+0, 1+2 and 2+1 (Orono only) and 2+2 from Orono and Midhurst nurseries were outplanted at Vivian and Larose forests. The purpose of the plantings was: i) to see if other stock types of red pine showed growth development and performance similar to the 3+0 stock type commonly used; and ii) to test the 1+2 stock type, which is a new red pine stock type. The significantly better performance of the 1+2 and 2+2 transplants observed at both outplanting locations in the first five years after outplanting suggests that 1+2 is a viable stock type alternative as a transplant.

(C. Glerum and J. Paterson)

Stock Characterization and Mulches

Two fields of nursery practice are being investigated: i) seedbed mulching with Fibramulch; and ii) nursery stock characterization.

For fall-seeded nursery beds, straw mulch was found to be superior to Fibramulch. Current work is evaluating application rate and properties of Fibramulch required to improve performance of just-seeded beds.

Top-root ratio was evaluated as a nursery stock characterization parameter. Bias in ratio calculation, difficulty in determination and unreliability as an independent parameter make top-root ratio less valuable than other measures. Stem diameter, top volume, root volume and root area were all better predictors of potential growth than top-root ratio.

Root volume is an efficient and reliable method for characterizing nursery shipping stock.

(G. Racey and R. Hutchison)

Stock-Type and Site Testing

Ontario tree nurseries produce several stock types of each coniferous species. Stock types are defined by age class and cultural treatment and have a specific set of physical and physiological attributes. Stock types are compared in an ongoing program to determine relative performance after outplanting. Current work will identify desirable stock types for regeneration of specific sites, with respect to physiography, competition and site preparation. Both the field and nurseries can use the information to select or produce the best stock for successful regeneration.

Shorter, more robust stock types that have endured stresses during the growing period in the nursery appear to be superior to lush, tall seedlings. Red pine 2+0 stock is superior to other stock types one sites with low competition. However, the 1+2 stock type is superior on sites with heavy competetion.

Five years after outplanting, white pine 1+2 stock had the best survival rate and height growth.

(G. Racey and R. Hutchison)

Black spruce stock types such as accelerated transplants, also called greenhouse transplants (i.e. 4G+1, 4G+2, etc.), are now being produced in large quantities at Swastika nursery. In cooperation with the nursery, the greenhouse transplants are outplanted with regular 1 1/2+ 1 1/2 and compared for field performance (i.e. survival and growth) as well as root development.

(J. Paterson)

Multiple-leader seedlings (i.e. black and white spruce) are frequently culled and/or are unacceptable to field staff. To determine how multiple-leadered stock performs after outplanting, several outplantings were conducted (Dryden, Timmins, Midhurst) with multiple-leadered stock as well as with single-leader stock. Results to date indicate that multiple-leadered stock performs as well as regular single-leadered stock.

(J. Paterson)

Conifer Storage and Handling

Spring and overwinter cold and frozen storage and related handling practices have been extensively investigated, and a continuing program is now in place.

White pine, scotch pine and white cedar store well at cold (1°C) and frozen (-3°C) overwinter storage temperatures. Stock should not be warmed up after frozen storage more than 28 days prior to planting.

Refrigerated cold storage is the best spring storage method and should be maintained until close to time of planting. Stock deteriorates in four to eight days of unrefrigerated storage and after about three weeks of refrigerated storage.

Current work in overwinter storage will develop an efficient and reliable method of determining the best fall lifting time for overwinter storage of coniferous nursery species.

Initial outplanting trials after root soaking show no clear benefits of soaking the roots of bare-root nursery stock prior to planting. Well handled, fresh stock continued to perform well. Additional handling steps associated with soaking increase risk of stock deterioration.

(G. Racey and R. Hutchison)

Larch Storage

Overwinter storage trials of European larch (Larix decidua), Japanese larch (Larix leptolepsis) and tamarack (Larix laricina), using late fall lifts during 1976-1979, showed no significant differences between stored and fresh spring-lifted stock with respect to survival, height or terminal growth after two to five years under outplanted field conditions. Due to the early season growth characteristics of all three species, the nurseryman now has the option of fall lifting to avoid springtime lifting pressures.

(C. Glerum, G. Racey and R. Hutchison, formerly R.E. Mullin)

Keith McClain is developing more effective nursery practices which will lead to better seedlings for forest regeneration.

Continuous Planting

Research plantations initiated ten years ago to elucidate relationships among stock type, time of planting and site will undergo their tenth-year assessment in 1985. Since 1981, plantations have been maintained in a competetion-free (mainly from aspen and jack pine) environment. Differential response in terms of height and current annual increment appear to have been maintained, suggesting that differences in a seedling's ability to establish itself and grow well can be manifested in substantial volume shortfalls at rotation. This has been already confirmed by previous work with white spruce in which a

600% difference in volume has been noted at 16 years between seedlings planted at different times and exhibiting similar survival rates, but with vastly different rates of growth.

(K.M. McClain)

Stock Conditioning

During a two-year (1981/82 - 1983/84) leave of absence, research was conducted at Oregon State University that pertained to altering seedling physiology to achieve better survival and growth on droughty sites. Douglas fir and jack pine were selected as experimental material and were grown for two separate but interrelated experiments. During the later phase of stock production, seedlings were conditioned by stressing to approximately -1.0 MPa during six cycles with and without applications of KCl at 100 ppm in the irrigation water. Non-stressed seedlings received similar amounts of KCl.

Throughout periods during which seedlings were subjected to drought stress, water relations were continuously monitored using the pressure chamber, and a vapour pressure osmometer. Various other parameters were estimated using pressure-volume curve analysis. Results indicated that only sequential stressing affected survival, and that differences in survival were not related to cellular alterations (e.g. radial and tangential cell wall thickness) but were related to the rate of decline in osmotic potential and total water potential. Douglas fir exhibited better survival as compared to jack pine. This was related to a greater rate of decline in total water potential per unit decline in relative water content. Under these circumstances, Douglas fir was presumed to maintain a larger gradient for the absorption of water than jack pine. Once relieved of drought stress, seedlings exhibited strong tendencies to grow well, suggesting that conditioning treatments were not detrimental to growth under favourable conditions.

The results confirm that benefits in the way of survival (and perhaps some growth) can be realized by conditioning stock previous to planting on droughty sites.

(K.M. McClain)

Stock Grading

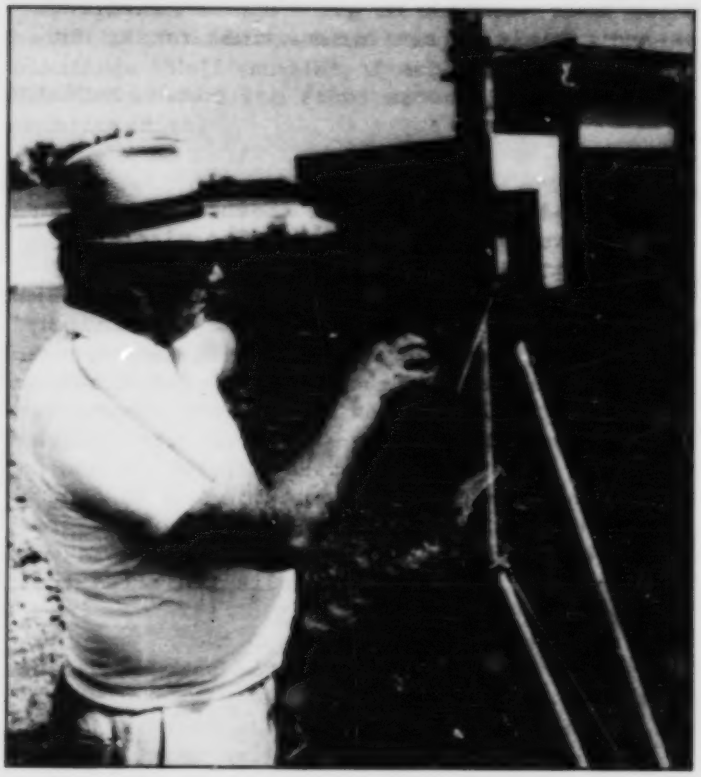
Morphological stock quality grading is the first step toward improved performance of nursery stock after field outplanting. A system of grading based on stem diameter and length, stem form, buds and roots is suggested for red oak. Preliminary grading standards are being worked out to be used in nurseries before bundling or on a planting site to avoid the cost of planting inferior stock, which will perform poorly.

(G. Stroempl)

Lifting and Root Pruning

Investigations are planned to determine the effects of various techniques of lifting and root pruning on the quality of planting stock at OMNR nurseries. The results should reveal the degree to which various lifting and pruning techniques influence the storage ability and root-regenerating potential of the stock after outplanting.

(G. Stroempl)



Chris Papadopol checks wind speed, air temperature, precipitation and humidity recorded by a computerized weather station.

Water Stress Effects on Biomass Accumulation

Two poplar clones (DN2 and DTAC8) were subjected to water stress of various intensities with a view to detecting changes in morphological and physiological processes involved in biomass accumulation. The experiment was conducted in a greenhouse, in five-gallon pots filled with equal quantities of Promix B artificial soil. The soil water reservoir was replenished with water up to certain predetermined moisture levels (50%, 70% and 90% of saturation) every two or three days. Transpiration was measured through weighing and subsequently correlated to leaf area of rooted cuttings. Direct transpiration measurements were accomplished with a LiCor porometer. In parallel, stomatal density counts were accomplished under the microscope in an attempt to determine whether the variations in water availability had influenced the leaf anatomy.

The results of the research indicate that the intensity of transpiration as determined through sampling with the porometer was consistent with water consumption as determined through weighing. Both poplar clones have characteristic stomatal densities which appear to be an intrinsic clonal trait unrelated to soil moisture conditions during their formation. Moreover, under similar conditions of radiation and atmospheric demand for transpiration, the flow of stomatal transpiration was controlled only by water availability, which accounted for a 1:5 ratio between the control (50% of saturation) and the highest water supply (90%). Porometrical measurements indicated that, when water was available, there was a very quick response in transpiration as soon as the incoming radiation, and with that the leaf temperature, increased. The response was reduced when water availability was diminished.

The influence of height and biomass accumulation revealed for both clones a ratio of 1:1.3 between control and 70% of saturation, and 1:1.4 between control and 90% saturation. In general, the leaf area of clone DTAC8 was 124% of that characteristic for DN2, while the ratio for total air-dry biomass was 114%.

When increases in biomass accumulation and transpiration intensity over the studied range of water availability are analyzed, it becomes obvious that biomass formation cannot effectively be augmented by supplying water beyond 70% of saturation; on the other hand, from 70% to 90%, transpiration increases dramatically. This feature can be used for the biological drainage of wet areas and/or for effluent disposal in intensive poplar cultures. While maintaining high accumulation rates, such cultures can dispose of water at rates at least equal to potential evapotranspiration, and potentially much higher, because of the heat mass transfer due to wind penetration.

(C. Papadopol)

Nursery Irrigation Based on the Atmospheric Demand for Evapotranspiration

A steady water and nutrient supply is an essential condition for the active growth of nursery stock. Water inputs, in the form of rain or irrigation, and outputs, as consumptive use and infiltration, change dynamically the availability of these two key elements. Moreover, since water must be present in the soil before fertilizer movement to roots can be initiated, the "hydrologic cycle" of the root layer is of great interest for correct management of water and nutrients. Two major circumstances interfere with the regime of water supply: the reduced thickness of the root zone, and the hydraulic conductivity of sandy soils. Because of root wrenching operations, the zone from which roots can draw supplies is limited to only 20-25 cm. Also, the high infiltration rate characteristic of coarse soils reduces the time water resides in the soil. These circumstances severely limit the amount of water that can be held in reserve by the soil layer that is explored by the seedlings.

Currently, the rate and timing of irrigation are determined by monitoring soil moisture depletion. However, considerable local bias is induced by soil non-uniformity, a fact that leads to over- or under-irrigation as compared to the real demand. Also, the peaks of evapotranspirational demand that appear frequently during summer days are sensed only indirectly by the current system. To remain on the safe side, operators tend to irrigate abundantly, ignoring the fact that the soil can retain only a limited amount of water, as well as the leaching effect of over-irrigation.

Irrigation rate calculation based on the atmospheric demand for evapotranspiration is one alternative with great potential for improving water and nutrient supplies. This approach requires the monitoring of changes in the atmosphere that control transpiration; potential evapotranspiration is then calculated according to a model currently used in irrigated agriculture. The potential evapotranspiration so calculated is then amended by a crop coefficient, and applied.

Equipment for data monitoring and appropriate computer software are needed to implement this approach. Since rapid changes occur during the

span of one day in several of the elements involved in calculations of potential evapotranspiration, a monitoring interval of one hour was chosen. In a typical operation, the data is collected every 24 hours and input into a computer. The computed irrigation rate is then applied, unless rain is forecast within the next 24 hours.

So far, this system has been implemented at two provincial nurseries: Chapleau and Thunder Bay. The existing package also includes a set of graphics for data display and analysis, showing the hourly evaluation of measured elements (temperature, solar radiation, relative humidity and wind) and of derived ones such as the vapour saturation deficit and potential evapotranspiration due to heat and to aerodynamic factors.

Further development of this system will require the determination of crop coefficients for major crops, and measurement of soil hydraulic conductivity up to the level of each compartment. A complex and fully integrated package for irrigation management, to include a water budgeting module that is updated daily, is now under development.

(C. Papadopol)

REGENERATION

Rejuvenating Older and Damaged Stands

Yellow Birch/Sugar Maple Regeneration and Recruitment

Performance Modelling:

A stand experimentally regenerated to yellow birch in 1960, located in the Swan Lake Reserve in Algonquin Park, was remeasured to obtain stocking and growth data on an area basis. A 100% cruise of all the trees with measurable diameter was made using 907 sample plots within the 2.5 ha experiment. Estimates and counts of regeneration <130 cm tall were also made. The original skidding pattern associated with the 1960 cutting was mapped through examinations of soil disturbance, skidding damage and cut pattern. Boundaries of the preparative prescribed fire were verified or modified through soil charcoal analysis.

Historical measurements of survival and growth were maintained on 52 microquadrats established in 1960 to follow performance of regenerated birch and maple. Survival patterns were fitted to modified logistic equations. Approximately 100 nested polar-plots were established, each centred about either a quadrat or other study tree, in order to provide specific distance-dependent stocking data for evaluating the relationship of quality to competition. Regression analysis indicates a negative relationship between dominant height and current overwood basal area and positive correlation between height and current peer (regeneration) basal area.

Correlations were better with randomly-chosen quadrat locations (R^2=63%) than with the larger sample trees purposefully chosen (R^2=18%). Analysis of the "azimuth effect", in which the competing basal area was

partitioned acording to bearing and distance, improved the correlation (R^2 of the sample trees was 38%). In an effort to improve the predictability for these larger trees, a "competition factor" (CF) was devised as follows:

$$CF = \sum_{j=1}^{N} \left[\left\{ \frac{(D.b.h._j)^2}{(D.b.h._i)^2} \right\} \Big/ Distance_{ij} \right] \quad \text{for N trees}$$

counted in a prism swing (BAF = 2.3 $m^2.ha^{-1}$)

Regression correlations with both height and diameter improved for the larger sample trees (R^2=74% and 56% respectively). These relationships are more difficult to interpret because they are index values; however, the relatively stronger correlations suggest that an overall distance-dependent competition control does exist. Work on this aspect is continuing.

Harvey Anderson

Up to this point, only current basal values have been considered in evaluation of competition. However, the original (1960) basal area probably played a crucial role in determining the rate at which trees attained dominance. There was sufficient overlap in the polar-plot distribution that, with a moderate amount of extra work, a complete tree-map of the experiment was made. Locations of all trees were stored in the computer as geometrically-computed coordinates consistent with that used as a map-base for the experiment. A superimposed sample grid was used to identify "critical trees" (ie. counted in a prism swing) surrounding each grid intersection, and increment cores were taken at D.b.h. for each tree. Annual radial increments were measured on a DIGIMIC system and each tree was "grown backwards in time", year by year to 1950. These yearly diameter estimates were used to compute basal area around each grid intersection in previous years.

From this data, and using a computer contouring programme, stand basal area maps for each year from 1960 to 1980 were constructed. These will be used in conjunction with the polar-plot and quadrat data to analyze the growth of sample trees relative to changes in basal area. Such information will lead to the evolution of optimum management prescriptions and cutting strategies which can then be field-tested.

Interspecific Relationships:

Vegetational dynamics associated with both burning and skidding were determined using continuous transects in the yellow birch experiment. Analysis demonstrated the scarcity of sugar maple regeneration in the burned portion of the stand despite the numerous seed years for the species since the initiation of the experiment in 1960.

New quadrats established in September 1981 containing permanently marked current-year germinants of sugar maple have been followed yearly for survival and growth. After three years, survival ranged from 0% to 40%, and averaged only 18%, indicating very poor regeneration potential, and confirming the observed rapid sugar maple seedling population turnover on the burned area. Since other local areas treated with prescribed fire at the same time (but not regenerated to birch) have regenerated well to maple, it seems that the occurrence of yellow birch is associated with the poor performance, rather than the burn. This suggests an allelopathic effect, which we will investigate in the near future.

(H.W. Anderson)

Rejuvenation of Poplar Stools for Improved Production

As juvenile poplar stools are cropped annually for propagation cuttings, an initial period of high productivity undergoes a general decline in stool vigour and growth. Perpetual severing of shoots from the aging, knobby and scarred stumps invariably leads to severe infestations by pathogens and insects, resulting in rapid general deterioration and spreading mortality among the propagation stock. There is now sufficient evidence that the condition and performance of stooling beds can be profoundly influenced by modified harvesting and management techniques.

With a view to improving sanitation, longevity and productivity of poplar stools, 30 Euramerican clones were harvested annually by cutting back the stumps at the ground level. Following a reduction in yield during the ninth and tenth growing seasons, the individual stools were severed approximately 5-7 cm below the ground surface. The treatment resulted in an appreciable increase in the number of new, vigorous shoots, which originated as suckers and tended to spread out in a cluster around the original stumps. At the same time, there was considerable proliferation of fibrous feeder roots close to the central axis and the surrounding suckers.

A 12-year evaluation of average stool productivity showed that, after subsoiling, the total number of stems per stool remained equal or improved in 73% of the clones, while linear yield remained equal or improved in 63%. Following the same treatment, maximum and mean shoot heights increased in 50% of the clones.

Examination and dissection of a number of roots after subsoiling showed no indication of infection or insect infestation. There is strong indication that stump decapitation and periodic subsoiling of the stumps can contribute to rejuvenation and extended shoot productivity of many poplar cultivars both in the nurseries and in energy plantations.

(P. Jaciw)

Regenerating Red Oak

Red oak is one of the eight hardwood species with a value higher than sugar maple, 34% more. Ontario now imports veneer logs of red and white oak, along with yellow birch and sugar maple. Good growth, high quality and high market value make red oak a desirable species to regenerate and grow in southern Ontario.

Final assessments are underway on the growth, volume and yield in two red oak-red pine plantations 38 and 50 years old, following thinnings since 1970. Preliminary results were described in the OMNR Forest Research Note No. 17, 1978. The oak outgrew the pine in both height and diameter. The addition of red oak to pine plantations on suitable sites provides an economic alternative to establishing pure pine stands, and also increases stand stability against mechanical and biological injuries.

Another alternative is to regenerate red oak by planting on hardwood sites where it presently is, or once was, a major stand component. A series of plantings under various stand treatments was established in the Algonquin and Central Administrative Regions between 1976 and 1983. The results should show the forest manager how to maintain an economically desirable oak component on suitable sites.

(G. Stroempl)

Hardwood Sprouts for Timber

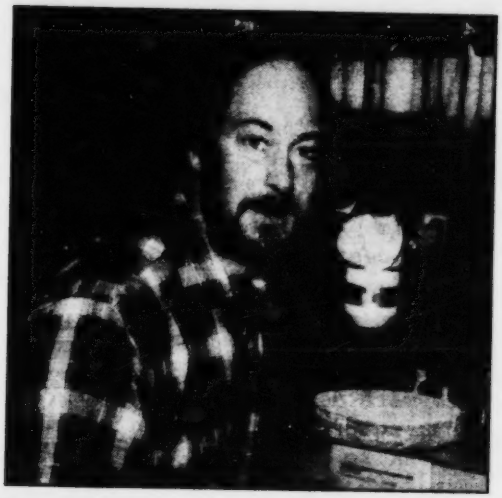
Many valuable southern Ontario hardwood species have an excellent resprouting capacity from stumps of cut younger trees, sometimes the only means of regeneration. The species, age of the trees cut, diameter and height of the stumps and the location of sprouts on the stump are the major factors influencing development of high-quality sprouts. A published report, Thinning clumps of northern hardwood stump sprouts to produce high quality timber (OMNR Forest Research Information Paper No. 104), summarizes the theory and methods of sprout development, and recommends how to thin clumps of sprouts. The report includes photographs which illustrate and describe practical examples of stump sprouting of white ash, basswood, red maple and red oak.

(G. Stroempl)

Quality and Variability of Aspen Regeneration

Trembling aspen regenerates following stand disturbances most frequently by the production of root suckers. This vigorous regeneration presents both opportunities and problems for the forest manager. If aspen has been designated as the main crop for the area, success of establishment and rapid capture of the site are almost assured. If, however, conifers requiring artificial regeneration are to be the main crop species, various treatments may be required to control the aspen and break up slash to allow easier establishment of the

desired species. Typically, a scarification treatment is applied, and may result in both positive and negative effects if the aspen is a secondary crop species.



Dave Weingartner

Four study areas were established in cooperation with the Atikokan, Geraldton, and Thunder Bay Districts to determine the effect of scarification on the quantity and quality of trembling aspen regeneration. Various light and heavy scarification treatments were applied in the spring prior to or during the initial period of suckering, and in the fall after one growing season. Sample plots were evaluated intermittently until the end of the fifth growing season in scarified and unscarified sections of the stands.

Analysis of the fifth-year data revealed that dominant height was significantly influenced in only one of the four stands. The one difference was the result of reduced dominant height in the fall heavy-treatment stand. Generally, the fall treatments tended to have shorter dominant heights than the controls, but not significantly shorter. Spring treatments, while not significantly different from the controls, tended to have a slight depressing effect if applied during the initial suckering period. The per cent stocking was significantly reduced in one stand by both the light and heavy fall treatments; however, with stockings of 91% and 90%, respectively, the treatments could not be considered to be too adverse. Spring scarification tended to enhance stocking on all areas, but not significantly. The lowest mean stocking for the four areas was 84% for a control treatment. Spring light and heavy treatments significantly increased stand density on two of the areas and slightly stimulated density on the other two areas, but not significantly. Fall scarification tended to slightly depress density, except where the lightest treatment was applied. The overall range in densities was between 14 000 and 34 000 stems.ha^{-1}.

After the fifth-season assessment, random stems were sampled in scarified and unscarified sections to evaluate the internal quality of the regeneration at each area. This portion of the work was done in cooperation wtih Dr. J.T. Basham at the Great Lakes Forest Research Centre. From the samples obtained, the results were inconclusive as to the severity and possible long-term development of defect. Previous work (see J.T. Basham's 1980 Information Report O-X-341 CFS, Dept. Environ.) indicates that the defect could be substantial in some cases. Samples will be obtained during the summer of 1985 from stands scarified 20 years previous, to aid in defining the long-term impact on defect.

As previously stated, scarification may have both positive and negative effects. It may control aspen density and growth if applied at the proper time and intensity, but if not judiciously applied it may possibly increase defect in this secondary species.

(D.H. Weingartner)

Effect of Cutting Method on Natural Aspen and Artificial Spruce Regeneration

Successful establishment and "optimum" growth of forest regeneration requires specific ecological conditions. Micro-climatic conditions encountered by regeneration are dictated to a great degree by the harvest method used to remove the mature stand. In many instances, the harvest method is selected for economic efficiency at the expense of future biological productivity. Clearcutting large blocks may be the most economical means of harvesting, as indicated by its widespread use; however, the micro-climatic conditions necessary for the establishment and growth of the regeneration may not be fully attained.

In cooperation with the Kirkland Lake District, five clearcut blocks of varying size and orientation were established in 1984. The primary objectives are: i) to determine the effect of clearcut size and orientation on aspen regeneration growth and biomass production; ii) to determine the effect of cutting method on the establishment and growth of planted white and black spruce; and iii) to evaluate the effect of early release on the growth and development of aspen and planted spruce in a mixedwood stand.

The clearcut blocks were harvested during the period from mid-April to the first week in June. Planting of the white and black spruce was completed by the last week of June. At the end of August, the survival of the spruce was good (90%+), and aspen suckers had filled in the area. Preliminary observations indicate that there is considerable difference in the growth of the aspen on the different clearcut blocks. Perhaps definite trends in the growth of all species will become apparent within the next few years, and will aid in establishing cutting methods more favourable for introduction of spruce on upland mixedwood sites.

(D.H. Weingartner)

Boreal Mixedwood Successional Trends

A major reason for conifer plantation failure on upland boreal sites is aggressive competition by fir, aspen, shrubs and grass. This study attempts to relate competition development to the method and intensity of site preparation and tending.

During 1981 and 1982, 465 milacre plots were established on mixedwood sites which had recently undergone wildfire or harvesting, followed either by no tending, or by scarification and planting with or without herbicide spraying. The first biennial assessments of stocking and growth were completed during 1983 and 1984. At least one more set of reassessments will be required to confirm the initial successional trends.

The first assessment has indicated a rapid domination of conifer regeneration by aspen suckers on most plots. Scarification did not change the relative competitive position of each species, but was associated with reduced height growth of aspen and shrubs. No significant differences in survival or height growth of conifers existed between scarified and unscarified areas. More abundant grass competition on scarified plots seems to counteract the effects of reduced aspen and shrub competition.

The early effect of wildfire was to promote aspen and eliminate fir as the dominant tree species. This was most pronounced on intensively burned areas. Shrubs had been reduced by the intense burn but regained pre-burn levels by the first assessment. Thus fire may be useful for controlling fir competition, but at certain intensities, it may promote excessive competition from aspen and shrubs.

(G.B. MacDonald)

Spruce-Fir Stand Dynamics and the Spruce Budworm

Stand dynamics, the study of change in the establishing, developing, maturing and overmaturing of forest stands, is an essential component of an understanding of forest productivity. In the life of a spruce-fir stand, the likelihood of a spruce budworm outbreak is almost inescapable. The effects of such a massive defoliation (perturbation) proceed through the stand as an energy transfer pulse which immutably alters the development of that stand.

Data collection was completed on a study to evaluate the effect of budworm on stand structure and development. This study will assist in developing the best silvicultural models with respect to spruce-fir stand structure, composition, survival and rehabilitation. Sampling of budworm oviposition, feeding, survival, etc. was carried out in conjunction with Great Lakes Forest Research Centre staff.

A series of long-term temporary and permanent sample plots established to study productivity on differing sites has afforded a remarkable opportunity to examine the effects on those stands of a major budworm infestation.

White spruce/fir plots were located in a widely scattered area across Ontario Site Region 3, about latitude 48°N at Dog River, Thunder Bay District; Blackwater watershed, Geraldton District; Heron Bay, White River District; and Chapleau-Folyet, Chapleau District. Red spruce/fir plots were located in Ontario Site Region 5, about latitude 45°N in south central and eastern Ontario.

Data from white spruce/fir and red spruce/fir plots indicate that both types of spruce/fir forests, while subtly different, respond very similarly to the budworm. Prior to a budworm event, spruce dominate the stand profile in overstory diameter classes distributed approximately from 10-60 cm in diameter. Balsam fir in the larger size-classes has long since dropped out or been eliminated. The rising secondary stand, however, which is expected to form the next crop stand, is dominated by fir in a ratio of about 7:1 fir to spruce, and frequently higher: 10:1 or even 12:1 fir to spruce. There are no balsam over 15 cm.

The regeneration under these stands is in the ratio of about 2:1 fir to spruce; however, this regeneration is unlikely to contribute to the next mature stand, since the rising secondary stand above it will shade it out.

After a severe budworm event, however, all the fir in the rising secondary stand are dead, as are many of the fir in the regeneration. The latter have been stripped by fifth and sixth instar budworm larvae which have spun down from balsam fir trees being stripped above. The more extreme the infestation, the more the fir regeneration below is eliminated.

Spruce, on the other hand, are almost all alive. Young spruce in the regeneration survive very well, and now represent a ratio of 1:2 or more (fir to spruce), more than the reverse of the previous condition. The overstory spruce are also almost all intact, and very quickly rebuild their crowns and commence flowering and seeding.

Two points may be made about fir. (1) The elimination of much of the rising secondary stand, along with much of the fir regeneration, releases young spruce regeneration which would otherwise have been lost through competition. (2) Since all fir in the 15 cm class and under has been eliminated, there will be no fir of flowering size left in the stand, and therefore no seed production on any fir for the next 20 years. This has the effect of permitting the seed being produced by the remaining overstory spruce to initiate more spruce regeneration in the openings provided by the dying fir.

An ancillary point is that defoliation of the fir is also transferred as an energy pulse in the form of nutrients in the larval frass. This nutrient is quickly available to existing small regeneration. The effect is also sustained over the next several years by the breaking up and return to the forest floor of the standing dead fir boles, branches and twigs and the nutrients that they contain, and their leachates.

The data in the foregoing have been used to develop a model which strongly supports two related hypotheses: i) that spruce budworm have, in fact, had a co-evolution with the spruce forest; and ii) that where spruce and fir grow together, budworm are an essential factor in maintaining spruce in the stand through time. That is, the reoccurrence of spruce is dependent upon the budworm to reduce the amount of fir. The corollary would be that if stands are sprayed to control budworm, fir is perpetuated, which in turn eliminates or drastically reduces spruce through competition.

The model does not address jack pine budworm, a single-host species system, nor spruce budworm in pure fir forests. The only immediate option in pure fir forests is more fir.

It should be noted that the establishment of long-term ecosystem sample plots, some dating back to 1959, has proven to be of enormous advantage in evaluating what actually goes on in the life of forest stands. Only with such hard data can we be in a position to predict the real effects of, for example, budworm on the spruce forest.

(A.G. Gordon)

Biomass Culture and Silviculture

Coniferous Biomass Productivity

Closely-Spaced Juvenile White Spruce:

In 1971, Dr. R.E. Mullin established an overwinter storage experiment involving lifting date and packaging treatments at Midhurst using 3+0 white spruce planted at relatively narrow spacings (1.22 m x 0.61 m, or 13 437 trees $.ha^{-1}$). Of the original nine lifting

treatments, only the earliest two fall lifts showed significantly poorer survival, suggesting ultimate stocking was determined early after planting. Upon completion of the test, the planting was made available for biomass assessment.

In 1983, at age 13 years from planting, average D.b.h. was 5.13+/- 1.44 cm and average survival was 91%. The trees were harvested, weighed and analyzed by component in September 1983.

Fresh weights and tree dimensions were determined individually for 1 118 non-sample (bulk) trees, using a tree-baler and electronic load-cell. Eighty-four sample trees were preselected randomly, proportional to occurrence by D.b.h. class, measured by components, and data was corrected to oven-dry basis. Stumps and root components were extracted by winch from 49 additional trees in September 1984. Regressions were used to partition total biomass into dry components. Border or edge trees were omitted.

Mean annual increment over the 13 years since planting for bole only, bole + branches, and bole + branches + needles amounted to 2.53, 3.84, and 4.94 odt.ha^{-1}.a^{-1} respectively. In addition, harvestable stump/root wood and bark would increase the oven-dry productivity by 15% over that realized from above-ground biomass only.

Juvenile Tamarack/European Larch:

In 1977, Dr. R.E. Mullin established an overwinter storage experiment at Midhurst with 2+0 tamarack and European larch planted at 1.52 m x 1.52 m spacing (4 300 trees .ha^{-1}). No significant differences in treatment effects were noted. Subsequent to completion, the planting was made available for biomass assessment.

In 1984, the plantation exhibited good survival (TAM=96.7%, E.L.=100%) and good basal area development (TAM=20.1 m^2.ha^{-1}, E.L.=35.5 m^2.ha^{-1}). The trees were harvested, weighed and analyzed by component in October 1984.

Fresh weights and tree dimensions were determined individually for 151 non-sample (bulk) trees using a tree baler and electronic load cell. Thirty sample trees were preselected randomly, proportional to occurrence by D.b.h. class, and measured by component (bole, branches, needles), and data corrected to oven-dry basis. Regressions were used to partition total biomass into dry components for each species separately. Border or edge trees were omitted.

As might have been suspected, European larch has developed considerably more biomass eight years after outplanting than tamarack. Mean annual increments for bole only, bole + branches, and bole + branches + needles were as follows:

- for tamarack: 2.03, 3.08, 3.53 odt.ha^{-1}.a^{-1} respectively
- for European larch: 3.25, 5.12, 5.78 odt.ha^{-1}.a^{-1} respectively.

(H.W. Anderson)

Species Introduction for Short Rotation and Biomass Projects

Genetic improvement of woodlots and plantations is a prerequisite for optimizing quality and quantity of future fibre yields.

Establishment and maintenance of select gene pools contributes directly to the production of quality stock and segregation of ideotype strains for optimum performance on a variety of sites.

Recently, work on the introduction and propagation of fast-growing species has been concentrated on black locust and European (black) alder. Together with the many sources of poplar, the two nitrogen-fixing pioneer species should appreciably expand the range of sites for the establishment of short rotation and biomass plantations. Also, they should facilitate rehabilitation of vacant depleted and marginal lands, and as nurse crops, provide intermediate cuts and improve yields in dual-crop forest systems. Due to considerable intraspecific variability of the two species, prospects are good for selection and propagation of hardy, well-formed and pest-resistant stock suitable for a variety of physiographic conditions of southern and central Ontario.

In this context, over 80 black locust seed sources have been assembled from native phenotypes and a considerable number of European selections. Best average germination was attained by one-hour treatment of seed with concentrated sulfuric acid as well as brief scalding with boiling water. For the acid-treated sources, the relatively high germinative energy required a period of four to five days and germinative capacity extended up to four weeks. The scalded seed showed a lower capacity and delayed reaction. Prolonged soaking of seed in hot water resulted in embryo damage and serious viability losses.

Sowing in tubes at the end of January gave excellent initial results, but by mid-May, most of the sources stopped growing and entered a period of semi-dormancy. After transfer from the greenhouse into shaded coldframes and application of additional watering and fertilization, growth had gradually resumed by the end of May. Due to a prolonged drought, planting of the tubelings in the nursery extended into late July. Fall inventory, however, showed satisfactory survival of over 70%, or about 6 000 tubelings. This was attributed to adequate watering and shading of the young trees during planting under the adverse midsummer conditions.

To prevent disruptive dormancy, future greenhouse sowing of black locust should be initiated in March in order to ensure uninterrupted seasonal development and maximum growth in one year. Some of the trees from all sources will be used in the establishment of a gene bank for future selection, improvement and propagation of superior planting stock. The remaining trees will be used cooperatively in testing the capacity of the individual sources for regeneration by suckering and sprouting, multi-cropping, reproduction by cloning, allelopathic influences and utilization prospects.

Presently, 15 additional black alder sources are being grown for the replenishment of the gene pool and for use in the proposed experimental plantings.

(P. Jaciw)

Effluent Disposal Combined with Intensive Silviculture

Modern civilization with its population concentration raises the sometimes enormous problem of human waste disposal. Cumbersome, sophisticated and costly treatment installations are needed to restore,

however partially, the purity of the liquid of which effluent consists before it can be discharged into running bodies of water. Growing environmental concern about this activity has led to rising standards of purity, which demand longer and more sophisticated treatment.

Human waste, normally consisting of protein decomposition compounds in various stages, may act as a much-needed food for trees. Rich in nitrogen, the waste appears to be an almost ideal substitute for the chemical fertilizers already used in commercial intensive forestry. At the same time, the waste has a large liquid component that is easier to vehiculate than sludge.

Forest vegetation consumes large amounts of water, but its needs are not always met, due to diminished soil water reservoirs. One way of meeting the moisture needs of the intensive forest is to supply it directly with the unsatisfied part of the atmospheric demand for evapotranspiration. This approach to irrigation differs from current sludge/effluent disposal practices, for which a natural or artificial stand on a site with permeable soil is chosen for year-round application of sludge and effluent. It is proposed instead to deliver small daily dosages of liquid effluent equal to the atmospheric demand for evapotranspiration, so that the whole liquid load will be exhausted only into the atmosphere. Sludge will be administered in annual dosages to match the rate of natural decomposition. These practices will be less likely to overload the ecosystem, and will greatly diminish the risk of groundwater pollution. The ecosystem will perform a true waste recycling function at rates it is capable of handling without harm. Moreover, the steady supply of water and nutrients will stimulate growth and further increase the recycling capability of the ecosystem.

While such a disposal/recycling system can be organized in a complex natural ecosystem, obviously the logistics are improved when we deal with a regularly planted forest composed of fast-growing and uniform trees.

The above framework, in which the ecological soundness of the operation prevails over convenience, formed the basis of one experimental plantation of several poplar clones established on the premises of Seneca College in King City, Ontario. The plantation was irrigated daily with effluent which had received primary treatment only. Poplars were chosen for this experiment because of several outstanding traits which make them highly suitable for recycling: i) high consumption of water; ii) high stomatal density that fosters easy transpiration; iii) permanent flutter of leaves that enhances transpiration; iv) high foliar nitrogen content that increases their reprocessing ability; v) fast growth that promises a quick increase of transpiration over potential evapotranspiration, as a result of increased leaf area and wind penetration in the stand.

The experiment is considered to be an innovative and ecologically sound approach to the problem of municipal waste disposal/reprocessing. Future studies will aim at quantifying the growth effects and assessing how effectively the forest ecosystem acts as a "true green filter". The greatest potential for implementation of this concept is for small and rural communities and for special institutions situated in isolated areas.

The multiple facets of this concept, including its economics, compare favourably with traditional treatment methods. Consequently, a pilot application for a locality with a population of 4 000 on the northern shore of Lake Erie is now being investigated.

(C. Papadopol and P. Jaciw)

Automatic Planter for Poplar Cuttings

The realization of high-density, fast growing cultures for energy from woody biomass, a major research topic in the frame of the Forestry Agreement of International Energy Agency, depends to a great extent on the planting operation. Given the limited time-span when this operation can be performed, not more than four to six weeks in Ontario, as well as the scarcity of workforce, mechanization appears to be the only alternative. Consequently, one of the projects of the agency is to explore innovative concepts related to the planting of hardwood cuttings, with potential for machinery development.

Cooperative project C4 listed Canada, Sweden and U.S.A. as participants, and was organized as a working body of nationally appointed advisors and hired consultants. During several meetings of the group, the merits and drawbacks of several concepts were evaluated with the aim of combining the best procedures for: i) packing of cuttings; ii) singularization of cuttings; and iii) planting. Special attention was given to the biological characteristics of cuttings, particularly to the fact that the buds of poplar clones break easily. Also, consideration was given to the versatility of the planter with respect to species, the considered ones being poplar, willow and sycamore.

Once consensus about the technical specifications was reached, a specialized firm in Sweden with experience in this area was commissioned to design the planter. The resulting design is composed of six planting sections that can be moved along a drawbar to form the desired planting configuration. The planter uses the so-called injection planting technique, in which the cutting is pushed into the soil flush with the surface. Careful soil preparation is a prerequisite of intensive poplar culture, making it suitable for this technique.

The design speed of the machine is in the range of 2 000 cuttings per hour and section. Thus, in five hours, this machine will be able to plant about two hectares at a density of 30 000 plants/hectare. Technically, the machine can operate up to double this speed, as long as no damage to cuttings is observed. The planter is fully automatic. Apart from the tractor driver, it needs an assistant operator for loading the cuttings in the sections' bins, as well as for maintenance.

The modular design adopted for this machine allows for various plantation configurations, and for a scaled-down version with fewer planting units suitable for the smaller pieces of land currently available in European countries. While conceived mainly for large-scale plantations, this planter also has very good potential for traditional nursery planting of poplar cuttings at about the same density, for which proper machinery is not yet available.

(C. Papadopol)

STAND MANAGEMENT

Hardwood

Sugar Maple Quality Dynamics

Wound-Type Relationships:

Computer analysis of defect originating from various types of wounds in maple polewood was continued. Correlation of stub-initiated defect (stain and rot) with branch size and scar age were computed for five stands, with resulting explained variation (R^2) ranging from 18% to 57%. Overall regression of the 727 samples had an R^2 value of 36% and implicated branch live age as an important variable.

The population of stubs was subdivided according to substrate condition and microfloral cultural result and recomputed using the same model. Correlation was not improved. R^2 varied from 9% for imperfect fungi associated with pith, to 37% for imperfect fungi in stained substrate. Provisional conclusions suggest that defect development is not controlled by the type of infection.

The majority of defect in maple is caused by stem wounding; recent analyses have dealt with fire, logging and sunscald wounds. Multiple regression analysis indicates that for both fire and logging wounds, stain and rot volumes are linearly related to original wound surface area. Preliminary comparisons suggest that for similar wound sizes, logging damage is more serious. In fire wounds, defect was analyzed for log lengths of 8, 12, and 16 feet. From 94% to 97% of variation in stain volume and from 70% to 79% of variation in rot volume were explained by regression. Original wound surface area, current basal scar age were important predictors. Sunscald damage is currently being studied, and appears to occupy an intermediate position between fire and logging in terms of severity.

Logging Damage Studies:

A cooperative study with Bracebridge District was undertaken in 1983 to evaluate the incidence and severity of logging-associated damage. Twelve polar-plots were established in a cutover in Finlayson Township, and all residual trees were mapped, measured and described with respect to logging damage. Skid trails were also mapped and the percentage of plot area covered by skid trail (skidding intensity) was calculated.

Preliminary analysis indicated that the proportion of wounded and damaged residual trees is linearly related to both skidding intensity and cutting intensity (proportion of basal area removed). Current studies are assessing the damage in terms of severity (ie. value loss due to injury).

Growth/Quality Modelling:

Relationships were developed to predict both current diameter and basal area increments of sugar maple polewood from measurements of tree attributes and stand stocking levels. Crown volume, crown position, and

point density were the principal variables in a regression which explained 85% of the variation in growth. It was also found that for both stub defect and fire wound defect, volumes were inversely related to stem volume increment in a hyperbolic model which suggested a minimum growth threshold might exist, above which the probability of significant defect development would diminish. This would seem to agree with the fact that healing rate is positively related to growth rate in a non-linear way.

Results suggest that the growth model can be used to predict future growth after wounding, which will affect wound healing rate and probability of defect development. Current studies will attempt to define a wound severity hazard in terms of size, type and location, which if used in conjunction with the growth model will lead to a method of predicting value potential for residual trees in cutover stands.

(H.W. Anderson)

Tolerant Hardwoods: Growth and Yield

Long-term studies of yields to be expected from the management of tolerant hardwood stands in southern Ontario are based upon almost 300 permanent sample plots. Table 2 indicates the distribution of these PSP's by District. A start was made to erect information signs near recently measured plots to facilitate their use by the District staff and public. The plots are remeasured at five-year intervals, or more often when a commercial or improvement cut is to take place.

It usually requires at least two cuts to bring some of the previously mismanaged "bushes" into a "managed" stand condition. During this development period, the growth of stem wood may be less than normal if the cutting has been too heavy. One objective of the study therefore is to determine the most appropriate basal area to be left after cutting to achieve the optimum quality yield.

TABLE 2 Number of permanent sample plots in tolerant hardwood stands by region and district

Southwestern Region		Central Region		Eastern Region		Algonquin and North Bay Regions	
Aylmer	13	Cambridge	21	Brockville	7	Algonquin Park	5
Chatham	9	Huronia	71	Carlton Place	8	Bancroft	13
Owen Sound	37	Lindsay	6	Cornwall	1	Bracebridge	4
Simcoe	8	Maple	12	Napanee	2	Pembroke	1
Wingham	11	Niagara	18	Tweed	5	North Bay	6
TOTAL:	78		128		23		29

(A.F. Beckwith)

Thinning of Hardwood Stands

To gain a better understanding of variable stand densities in woodlot management, work was continued on the long-term effects of experimental thinning in a low-quality sugar maple (basswood-ash) stand near Chatsworth, Ontario.

Comparisons of the periodic sugar maple increments in the heavily and moderately thinned plots and controls indicated a consistent reduction in both diameter and basal area growth rates for the four consecutive five-year periods as shown in the following table (Table 3):

TABLE 3 Percentage of basal area growth rates by periods and treatments

Period	Control	Moderate thinning	Heavy thinning
	%	%	%
1	2.9	3.8	5.5
2	2.5	3.2	4.3
3	2.0	2.5	3.2
4	1.8	1.8	2.0

Evaluation of the individual crown classes over the 20-year period showed that the growth rates of the codominant trees in the heavily and moderately thinned plots tended to be consistently higher than those of the dominants. In controls, growth differences between the two classes remained negligible. Towards the end of the period, growth of the dominant trees in all stand densities practically equalized; however, relatively superior growth rates were still maintained by thinned codominant, intermediate and suppressed trees. This was particularly evident in the heavily thinned plots.

Recent dendrometer measurements taken on over 200 sample trees indicated a relative improvement of sugar maple growth in all size classes and treatments. This may be due to a combination of factors such as improved growing conditions during consecutive years, recovery from recurring defoliation by forest tent caterpiller, and a progressive opening up of the stand as a result of natural mortality. There was every indication that serious consideration should be given to corrective pruning of hardwoods. When carried out early in the rotation, it would greatly enhance quality and reduce injuries and losses among many of the potentially valuable high-risk trees.

(P. Jaciw)

Dynamics of Stand Structure and Stocking in Uneven-Aged Tolerant Hardwoods

Changes in Structure and Stocking over Time:

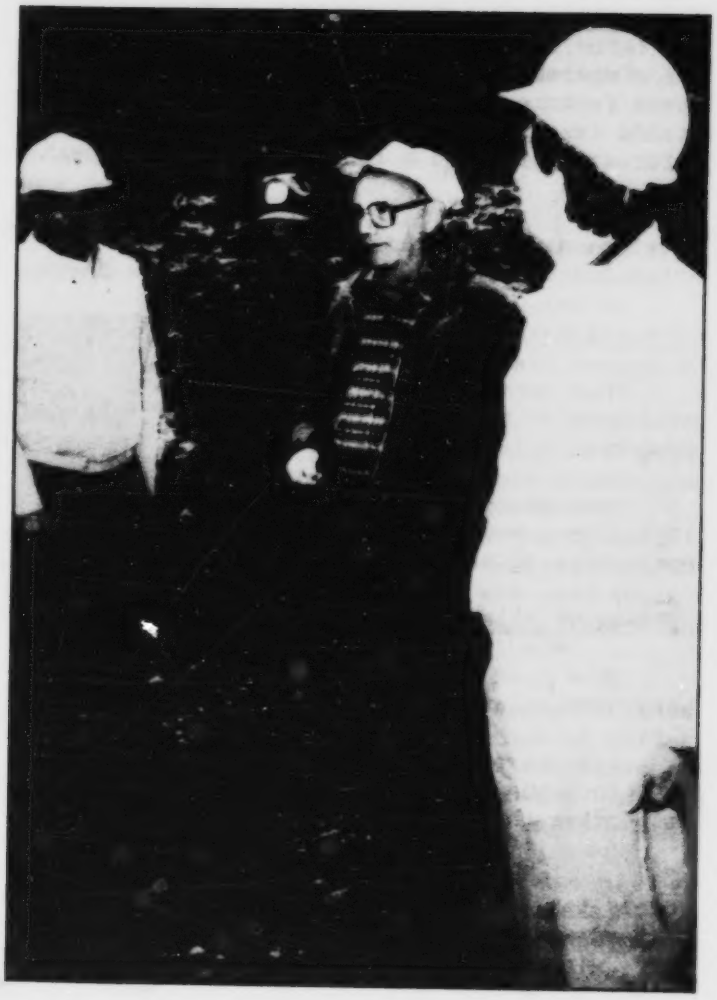
This study is intended to provide insight into the phenomenon of natural change and development of this forest through growth and mortality, in undisturbed stands. Fourteen 0.7-acre plots have been measured at intervals since 1969, last in 1984. This data provides material for instructional purposes.

Changes in Structure and Stocking within a Stand:

This study demonstrates the continual change from place to place in what often are considered to be uniform, undisturbed old-growth stands.

Fifty-one plots of various sizes and shapes are photographed annually and measured at longer intervals, to serve as models for discussion and instruction.

(M.M. McLean)



Mac McLean (third from left) explains how forest management and silvicultural procedures can optimize production of quality hardwoods

Growth of Tolerant Hardwoods after Commercial Logging

Management by Selection System:

After two selection cuts, in 1968/69 and 1981/82, 25 one-acre plots were measured once again to determine growth and development of a stand under intensive management and control.

The information will be used to compare with that for uncut stands and for cut but unmanaged stands.

Unmanaged, High-Graded Stands:

Five-year remeasurement data was obtained from 268 0.1-acre plots which had been established in 1977 on areas logged eight to 20 years previously. This information was used to refine growth models developed by Dr. F. Raymond for the guidance of forest managers in their planning and silvicultural programs.

Such cutover stands are similar to those with which forest managers must work in the near future.

Ingrowth and Mortality Study:

Development of stands after cutting depends to a great extent on these factors. Ninety-five 0.1-acre plots were established in three stands immediately following cutting to provide more detailed information for the purpose of refining growth models.

(M.M. McLean)

Development of Tolerant Hardwood Polewood after Pre-Commercial Thinning

Crown Release of Crop Trees:

This treatment was made in 1960 in a 45-year-old stand of tolerant hardwoods to determine the efficacy of such operations in improving crop tree growth.

Remeasurements of ten 0.2-acre plots at intervals and finally in 1983 form a basis for reporting results and for making recommendations respecting this silvicultural approach.

Cutting of All Non-Crop Trees:

This treatment was made in 1968 in a 62-year-old stand of tolerant hardwoods in an attempt to maximize growth of the best-quality trees.

Remeasurements of 33 0.1-acre plots at intervals and finally in 1983 form the basis for reporting results and for making recommendations respecting this form of thinning.

(M.M. McLean)

Models for the Cutting and Response of Hard Maple in Hardwood or Mixedwood Stands

A pair of models has been developed, jointly with M.M. McLean, on microcomputers for simulating the growth and yield of the hard maple component of hardwood or mixedwood stands in the Algonquin Region. One of the models "grows" the maple for up to four five-year periods from any given stand table. The other accepts the original stand, with or without the simulated growth, and allows the user to perform partial cuts according to one of several definitions of "desired postcut stocking."

Used together, the models allow the user to examine a mixture of strategies for various lengths of cutting cycles and for partial cutting or clearcutting in various diameter classes. Although the simulations are slightly biased, the patterns of development they illustrate appear to be reasonable. This permits the user to explore patterns of subsequent impact of cutting too heavily in the next several cycles.

(F.L. Raymond and M.M. McLean)

Algonquin Regional Growth Study

The Raymond-McLean model for response to partial cutting in hardwood or mixedwood stands, reported for 1981/82, was based on descriptions of, and cores from, trees on 268 0.04 ha (0.1-acre) permanent sample plots made in 1977. This regression model was developed in Fortran on a PDP-10 and was rewritten in BASIC for an HP87.

The 263 plots not cut in the interim were reassessed in 1982. These records, including those for recruited trees, have been added to the 1977 data. The enlarged basis will be used for reformulation and verification of the model during 1983/84.

(F.L. Raymond and M.M. McLean)

Tending High-Quality Stands

The growth response of basswood, over one-half of sprout origin, and sugar maple to an intermediate cutting at a stand age of 52 years was followed for 12 years in a stand where both species were represented in the main canopy of the stand.

George Stroempl

Sugar maple responded positively in diameter and volume growth, but basswood showed no definite increase in growth, partly as a result of crown deterioration. However, basswood exceeded sugar maple in clear bole length and log quality.

The differential response to this cutting is a reflection of differences in shade tolerance between the intermediate basswood and very shade-tolerant sugar maple.

Early stand tendings are the main silvicultural implications, ie. to retain basswood's original height advantage and its high proportion throughout the rotation over the oppressive maple. These and other factors are documented in a published research report (Growth response of basswood and sugar maple to an intermediate cutting. OMNR Forest Research Report No. 17).

(G. Stroempl)

Softwood

Natural White Pine Management

The need for growth and yield information on previously unmanaged natural stands is growing as the intensity of forest management in south-central Ontario increases. Of particular interest because of its relatively high value is white pine.

A thinning experiment set up near Achray in 1953 combines testing of thinning type and intensity in natural semi-mature white pine and red pine. The study encompasses fourteen 0.4 ha permanent sample plots: three unthinned, two free-thinned, four thinned from above and five thinned selectively. Within both the selection and above thinning, a range of residual basal areas existed. Periodic remeasurement of the plots occurred until 1979, at which time a second thinning took place.

The 25-year response to the 1953 thinning has been analysed. Trees removed in this second thinning were scaled, and a sample of them was used for stem analysis. These trees provided the basis from which comparisons of local, standard, form class and product-form volume equations were made. Some of the equations were unable to estimate small tree volumes accurately. Since small trees constitute only a small proportion of the total volume in a mature or semi-mature stand, the equations were tested for accuracy on an independent sample of trees greater than 15 cm D.b.h. Product form which uses D.b.h. and height x mid-height diameter showed the best results.

The data collected from plot measurements were entered into computer files and checked for inconsistencies. These data are the basis for analysing the different thinning techniques applied in 1953. Applying the product-form volume equation, plot volumes were calculated along with average height, diameter and basal area. Results of this study show that consistently better growth can be achieved by thinning in such semi-mature stands. The volume of larger diameter trees generally increased with the intensity of thinning. This more desirable volume distribution has significance for logging and utilization of higher quality lumber. Detailed findings were summarized in Forest Research Note No. 35, "Initial Thinning in a Semi-Mature White and Red Pine Stand."

(D. Andison, P. Roebbelen and A.F. Beckwith)

Jack Pine Plantations: Growth and Yield

Some of the older jack pine plantations in northern Ontario have reached an age at which they can be thinned commercially. Two such stands have been thinned recently to evaluate the effect upon current growth and future yield. These were areas which had been planted in 1955 as part of a jack pine provenance trial set out by A.J. Carmichael in the early years of seed source studies. One was in Cane Township, Kirkland Lake District, and the other in Maria Township, Algonquin Park District.

Since the primary objective of the study was to record the performance of jack pine populations from widely separated points in Ontario, the thinning treatment had to be superimposed upon the original experimental design. A cross-row thinning technique was used which approximated removal of 1/4 of the stems. The cutting and skidding was done cooperatively with local District support. A sample of cut trees was scaled on each plot, from which the volume of individual trees was obtained. Local volume equations which reflect the variation in form of trees due to different causes were developed. These will assist in the calculation of future growth and yield in these and other plantations. The study will facilitate analysis of the effects of thinning upon individual tree development and stand growth.

A similar study of the effects of thinning to differing densities has been progressing in Hendrie Forest of Huronia District since 1948. Growth tables relating to different density regimes were presented at the Jack Pine Symposium in Timmins in November 1983. They estimate the gross total volume and basal area yields to be expected in five-year periods from stands thinned by 0% up to 50%. It was shown that these estimates would be applicable to jack pine plantations growing on a similar site class in northern Ontario. The data base must be expanded to cover a wider range of sites in the north.

(A.F. Beckwith)

Red Pine Plantations: Growth and Yield

Forest Research Report 108, "Red Pine Plantation Growth and Yield Tables," was the culmination of over three decades of monitoring permanent sample plots (PSP's) in red pine plantations. The tables are based on 306 measurement periods on 87 PSP's located primarily in site region 6E (Hills 1961).

Forest management decision-making requires that future growth and yield be estimated accurately, particularly where there may be a choice of end product. For example, a manager may wish merely to maximize total volume, regardless of stem size; or may wish to produce the greatest number of a specific product such as poles; or may be interested in growing trees of the highest possible lumber quality. For these objectives, the manager has available a variety of alternative thinning schedules. By knowing the consequence of each alternative, the manager can select and realize a specific objective.

The growth and yield tables presented in this report can be used to forecast the outcome of various thinning regimes. Thus foresters can design thinning schedules to meet desired objectives.

The tables refer to 20- to 60-year-old plantations with initial spacings of 1.7 m x 1.7 m to 2.3 m x 2.3 m, but the majority of the plantations have been planted close to the 1.8 m x 1.8 m spacing.

There are five types of table, giving information on: i) present yield; ii) normal yield of unthinned stands; iii) projected yields after thinning; iv) individual tree volume and v) site index. The tables are presented in S1 and Imperial units.

The major portion of the report deals with the estimation of gross total volume (m^3/ha) and basal area (m^2/ha) growth and yield for a range of thinning levels (including 0% thinning) five years after the treatment has occurred. The tables allow the evaluation of yields from various thinning regimes for a plantation up to the age of 65 years.

A smaller pocket-sized version of the report has been prepared for field use.

The work of monitoring the growth of red pine plantations is continuing. Table 4 presents the distribution of the PSPs included in our red pine program. Not all of these have been used in the research report.

TABLE 4 Location of pure red pine and mixed red pine/white pine permanent sample plots by region and district

Central Region		Eastern Region		Southwestern Region	
				Owen Sound:	11
Huronia:	114	Brockville:	4		
Maple:	30	Cornwall:	5	Northeastern Region	
		Tweed:	1	Blind River:	9
				Algonquin Region	
				Bracebridge:	3

The initial stand conditions of a plantation have a great effect upon its subsequent growth. Data from 30 available plots planted to red and white pine have been prepared for analysis. This will allow comparisons with the results of pure red pine plantings on a stand basis. It is already known that on drier sites, as a consequence of early white pine mortality, the initial mixture of red and white pine produces larger individual red pines than in pure stands.

(A.F. Beckwith and P. Roebbelen)

Spruce Plantations: Growth and Yield

The last decade has seen a dramatic increase in the time and effort devoted to the regeneration of spruce sites by planting. This same time period has also seen increasing concern by many foresters over the lack of information for our northern plantations.

In 1980, a program was initiated to study the growth and yield of white (Picea glauca (Moench) Voss) and black spruce (Picea mariana (Mill.) BSP) plantations. By the end of the 1983 field season, some 253 permanent sample plots (PSPs) had been established in ten administrative districts throughout northern Ontario (Table 5) within site regions 4E, 3E, 3W and 4W (Hills 1961).

TABLE 5 Distribution of spruce permanent sample plots by district in the province of Ontario

Location	Number of plots		
	Sb	Sw	SbSw
Northern Region			
Kapuskasing District	44	9	6
Cochrane District		17	
Kirkland Lake District		14	
Timmins District	9	5	
Hearst District	2	25	2
Northeastern Region			
Wawa District	7	12	
North Central Region			
Thunder Bay District	7	9	
Terrace Bay District	12	1	
Nipigon District	43	9	2
Geraldton District	9	7	2
TOTAL:	133	108	12

The oldest plantations are 28 years old. Through the measurement of annual height increments and through stem analysis procedures, we are beginning to gain a fuller understanding of the development of young plantations on a variety of sites. The relationship of productivity to site is considered to be critical for proper stand management. Detailed soils and vegetation data have been gathered for each plot. This data will be used initially to correlate stand growth to soil types. The

site/productivity relationships developed in this study will allow us to classify potential planting sites by the estimated yield at harvest.

Preliminary analysis of the height and volume data gathered from initial measurements of the PSPs indicated that plantation yields per unit area will be higher than the production recorded in natural stand yield tables, given full stocking and similar site conditions.

A significant outcome of the study will be the assessment of the many management inputs in terms of growth and yield responses. Accordingly, as much information as possible is being gathered on the scarification, planting and tending techniques employed in the plantations we have sampled (Table 6). The quantification of these treatments will aid the forester in planning an effective management strategy for growing spruce.

(P. Roebbelen)

Balsam Fir: Growth and Yield

Although fir is being more widely used in northern Ontario to meet the demand for conifer fibre, management of the species is hampered by a lack of basic growth and yield information. This study will produce silvicultural guidelines for balsam fir through modelling volume growth in relation to stand factors and decay status.

Blake MacDonald

Growth and decay analyses have been completed for 2 500 trees from 30 plots on upland sites across the North Central Region. Regression models are being developed to relate stand growth to factors such as density, age, per cent decay and site type. When the most significant factors are determined, recommendations will be made regarding the manipulation of these factors to improve yields.

Since plots were established on similar sites, only stand and tree factors are significant in the regression analysis. Soil depth, texture, moisture regime and pH account for very little variation in yield, while density, age, and per cent stocking to fir account for much of the variation. Volume production up to 90 years of age is consistently higher for fir than for site-class-one black spruce in Ontario. The analysis of gross volume leads to the recommendation of short rotation ages for fir, 46 years for bole biomass and 58 years for merchantable pulpwood or sawlogs. This compares with 75 and 84 years respectively for site-class-one black spruce. Early harvesting of fir is also supported from a pathological standpoint. Volume growth rate appears to be reduced by basal decay exceeding 20% of stump area, amounts common in trees over 70 years of age.

(G.B. MacDonald)

TABLE 6 Distribution of plots by site disturbance/site preparation, stock type and tending history.

	number of plots		
	Sb	Sw	SbSw
Site disturbance/site preparation			
wildfire burn	44	22	1
wildfire burn, V-bladed	4	1	
wildfire burn, anchor chains		8	
prescribed burn	12		
old field	24	4	
old field, disc and root rake		6	
old nursery	4	4	4
Marden chopper	14	5	
Marden chopper, furrowed		17	
Young's teeth		5	
barrels and chains	8	3	
V-bladed	4		
shark fins		5	
unknown	8		3
TOTAL	122	80	8
Stock type			
2 + 0		1	
2 + 1		2	
2 1/2 + 1 1/2	12		
2 + 2	55	44	8
3 + 0	15	5	
3 + 1	6		
2 + 2 and 2 + 3		6	
2 + 2 and 3 + 0		8	
2 + 2 and 3 + 1	7		
2 + 2 and 3 + 2	12		
2 + 3 and 3 + 0	2		
2 + 2 and 3 + 0 and 3 + 2	3		
unknown	10	14	
TOTAL	122	80	8
Tending history			
hand clean	54	18	1
aerial spray	8	28	
hand clean, aerial spray	22	6	1
thinning (every 3rd row)	4	4	4
not tended	13		2
unknown	21	24	
TOTAL	122	80	8

Mixedwood

Mixedwood Forest Growth Models

The natural boreal mixedwood forest represents a large fibre reserve which will increase in importance as pure stands of spruce and pine are depleted. Mixed stands will always be significant because of the aggressive invasion of plantations by fir and aspen. This study attempts to model growth and competition dynamics in mixedwood stands, and ultimately will produce silvicultural guidelines for this extensive forest type.

Six circular plots 0.2 ha in size containing a total of 3 000 trees have been established in pole-sized natural mixedwood stands and plantations with heavy competition from aspen. The accurate mapping and stem analysis of all trees allows an investigation of the relationship between stand structure and the increment of stands or individual trees.

Vertical competition (degree of overtopping) and horizontal competition (degree of crowding) appear to be equally important regarding volume increment of all mixedwood species. Stand-level factors are more closely correlated with stand volume growth than are tree-level or site factors. An inverse relationship exists between growth and competition level for all species, and the degree of shade tolerance affects the strength of this relationship. The growth models are being refined by improving the method of quantifying competition level. The final models will assist management by simulating the outcome of specific harvesting and silvicultural operations in mixedwood stands.

(G.B. MacDonald)

Thinning Aspen in the Boreal Mixedwood Forest

In anticipation of a province-wide increase in the demand for aspen by the year 2000 and the current demand in local areas, an aspen thinning study was established in cooperation with the Dryden, Terrace Bay and Timmins Districts. Stands ranging in age from five to 20 years were systematically thinned to specified densities between 400 and 2 500 stems.ha^{-1} to determine the biomass available from thinning, and the effect on the growth and yield of individual trees and stands.

Biomass:

The thinning treatments removed 80% to 99% of the standing crop and represented aspen biomass yields on the order of 15 to 80 metric tonnes .ha^{-1} for the previously untreated stands in the study. Preliminary regression equations relating total bole volume to fresh and oven-dry weights of the total tree and tree components (peeled bole, bark, branches, and leaves) were developed for use in stand biomass equations.

Growth and Yield:

Preliminary analysis of the data for the three five-year-old stands indicates that the released trees are responding to treatment with increased diameter and volume growth. Five growing seasons following treatment, the mean tree in one stand contained 29% to 45% more volume in the thinned plots than the same tree in the control

plots. However, total stand volume in the thinned plots was between 2% and 7% that of the controls. Estimates of when or if stand volume in the thinned plots would equal that of the controls were impossible to make after five growing seasons, but estimates should be available following the tenth-year reassessment in 1989. In any case, it appears that the time required to produce a merchantable stem can be reduced substantially.

Reassessments of the stands in this study over the next several years should provide the data needed to prepare a preliminary growth model for thinned and unthinned aspen.

(D.H. Weingartner)

Growth Measurement Techniques

Automated Ring Measurement System

A system that automates ring width measurement and the subsequent processing of the data is now in place. Annual ring width data, produced by the Holman DIGI-MIC tree ring measurer, are transmitted to an Apple II Plus microcomputer, after each radius on a stem cross-section is measured. The interactive computer program allows the operator to display the ring widths as line graphs on the screen, make comparisons with measurements of a previous radius or the average of several radii, edit the data if required, and store the verified material (individual values and averages) on floppy diskettes.

For further processing, the data on the Apple diskettes are transferred to a PDP 11/23 where a series of Fortran programs formats the data into a two-dimensional array of ring widths by year and section height, and calculates cumulative radii, areas and volumes. Graphs of growth layer and stem profiles, volume curves, etc. are then produced on a Tektronix 4051 microcomputer with 4662 plotter.

Developmental work on the hardware and software components is in progress for an "off-the-shelf", automated, self-contained, ring measuring system with computational and high-quality graphics capabilities at relatively low cost. The system is based on the Sony Magnescale electronic ruler, an Apple IIe microcomputer and Hewlett Packard HP 7470A plotter.

(D.C.F. Fayle and D. MacIver)

Stem Growth and Development Patterns

The establishment of the automated tree ring measuring system and its associated computational and graphical outputs has greatly facilitated the ability to examine growth and development patterns using detailed stem analysis techniques. Current studies focus on various sequential changes that are found in the growth-layer profiles of ring width and ring area, and how these are related to changes in crown structure and dimensions. An understanding of these relationships will improve the assessment and interpretation of growth in response to past treatments or environmental conditions, as well as the prediction of future performance. The measuring system is also now being utilized for mensurational studies.

(D.C.F. Fayle)

SITE

Regional Ecology

The focus in this group of projects is on the recognition, description and mapping of site regions, being the highest level of a hierarchical site classification system for Ontario. The site region concept is being extended to provide a continent-wide framework which aims to show practitioners and researchers alike how the distribution and growth of tree species in relation to specified positions in the landscape differ among regions, reflecting differences in macroclimate. Such a framework could assist in a more effective transfer of knowledge and management practices within and among regions.

Dys Burger's work provides a framework for the long-distance transfer of biological, silvicultural, and mensurational knowledge, as well as management practices.

Site Regions of Northeastern North America

Extension of the site region framework south from Ontario has already resulted in a published preliminary map for the Lake States, and current work reaches as far south as 35°N and from the Mississippi River to the Atlantic Ocean. For that area, about 200 publications covering the period up to 1983 have been reviewed, and a concept map has been drafted at a scale of 1:10 000 000 and for mountainous areas, at a scale of 1:3 000 000.

(D. Burger)

Climatic Ecoregions of Canada

Work towards a map and report on Climatic Ecoregions of Canada is progressing slowly. This undertaking of the Ecoregion Working Group, established in 1978 under the auspices of the Canadian Committee on Ecological (Bio-Physical) Land Classification, relies heavily on correspondence, mainly from volunteer federal and provincial researchers. Two drafts of a national map (scale 1:7 000 000) have been circulated, and contributions towards the report have been distributed.

(D. Burger)

Site Regions of Ontario

The above two studies, in which the site region concept developed for Ontario is being extended to cover the whole of Canada and adjoining areas in the United States, have led to the realization that some adjustments in the definitions and boundaries of the Ontario site regions are warranted. It has also become apparent that the scientific basis for establishing site regions and their potential function and use for management require a more elaborate treatment than is currently available. The revisions will be kept at a minimum to avoid major changes in current management applications. A manuscript for a report and a revised map are being prepared.

(D. Burger)

Regional Forest Ecology, Northeast China

Northeast China and Ontario have many forest tree genera in common, and there is a remarkable similarity in forest physiognomy and regional species distribution. With the increased interest in and opportunities for the exchange of forestry information, assistance and trade, an understanding of forest ecological conditions in northeast China may be useful. Attempts to recognize and describe site regions for that area were enhanced considerably when Mr. Zhao Shidong of the Institute of Forestry and Soil Science, Chinese Academy of Sciences, Shenyang, Liaoning, P.R.C., visited our Institute several times to participate in a field tour and writing sessions. A first report dealing with a preliminary comparison of forest ecological conditions in northeast China and Ontario is well under way.

(D. Burger)

Consultation, Forest Soils, Burma

At the invitation of the College of Environmental Sciences and Forestry of the State University of New York, Dr. Burger participated from July to September 1982 as a consultant in forest soils in a project of the United Nations Food and Agricultural Organization (FAO) to establish a forest research institute at Yezin, Burma. A fairly well equipped soils laboratory had already been established, but a research program needed to be formulated.

From discussions in Burma with senior forestry staff, it was agreed that an outline of a site classification system should be provided: i) for assessing and explaining successes and failures in survival and growth of planted teak in moderately dry tropics and of other species in the dry Savannah zone; ii) for permanent sample plots of the forest inventory; and iii) for watershed management and erosion control.

A review of available literature on forest types, soils, geology, climatology and hydrology revealed a lack of information on forest soil and no available ecological national framework useful for forestry; the forest typology lacked the soil and climate component.

Given the needs of management, the scattered information in the literature, and the limited available scientific and technical expertise in Burma, an outline for a relatively simple four-level physiographic forest site classification system was developed. A provisional map of Forest Site Regions for Burma was made with descriptions to show how ecological relationships between forest types and positions in the landscape vary among climatically different regions ranging from the tropics to the temperate (Himalayan) climate and from the very wet maritime coasts to the dry Savannah. Within such site regions, it was demonstrated how geological maps and descriptions could be used in the establishment of "parent soil material types" at the second level of classification. The concept and description of "physiographic site types" (soil and local climate) as part of the ecosystems were dealt with, and several research problems were identified. At the fourth level, soil series as recognized in soil surveys and local variations of erosion, humus types, etc. could be fitted in.

For four ecologically different areas, research programs were proposed, comprising problem formulation, research objectives, strategies and locations for field activities. These locations would also provide opportunities for cooperation between researchers and field managers and could serve as demonstration areas.

(D. Burger)

Forest Ecosystems

Acid Precipitation

The recognition of the widespread effects of long-range transport of acid precipitation prompted the federal/provincial LRTAP Acid Rain Research Monitoring Committee to undertake a working field trip in conjunction with the U.S. Forest Service. Such a trip took place in August 1983, with delegates from Canadian federal and provincial agencies and U.S. government and university agencies. Eleven delegates were joined by several local representatives.

Acid precipitation sites at Mt. Whiteface, northern New York; Camel's Hump, Vermont; and Mt. Washington, New Hampshire were visited. Soil pits, diameter increment, regeneration, tree damage, root mortality, ground vegetation, epiphytic lichens and mosses were examined. Weather/chemistry data sets were made available at each monitoring site; several presentations were made, and many intensive discussions were held.

Consensus regarding the possible effects of acid rain in the high-elevation forests of these U.S./Canadian border states were as follows:

(1) Negative effects on the forests declined generally from west to east, but there was marked mortality in spruce at Camel's Hump, Vermont, as well as at Mt. Whiteface, N.Y. Deterioration was most severe at high

elevations, and hardly noticeable at low elevations. All size-classes were affected. The condition was most severe in red spruce, less so in balsam fir, and least in white birch. Younger age-classes of red spruce regeneration, while sparse, seemed unaffected, even in areas of extreme dieback of mature trees. Regeneration of white birch, alder, white pine (where present), and balsam fir also appeared vigorous. Epiphytic lichens and mosses were also quite healthy in much of the upper spruce-fir zone.

(2) The striking mortality of fir, occurring in the high elevation 'fir waves' (elevational bands of dying or dead fir) throughout almost all of the mountains of the northeast, is not related to acid precipitation, but is part of a long-established natural successional event continuously occurring in the high-elevation fir forests.

(3) Through aging spruce regeneration, dry years leading to seed production were identified. Recall of massive regeneration losses in all-aged stands, from plot sampling in Algonquin and eastern Ontario, corresponded to a year of massive depletion in reservoir water in New York State in 1964. Subsequent dry years were indicated. Confirmation was obtained from spruce increment cores (Fayle) that growth in these spruce was markedly affected from the early 1960s. Some trees showed initial recovery and subsequent decline.

(4) Pathalogical aspects, root and stem diseases which are acting strongly in some of the processes of the decline, were not deemed in themselves to be acting as primary causal agents initiating decline.

(5) Following much discussion on forest soils, nutrient uptake, and foliar concentrations, as well as the information on soil water, precipitation and cloud chemistry, it was agreed that despite some positive correlative and suggestive relationships, evidence that acid precipitation was the sole factor causing the forest decline was not possible to confirm.

However, the working-group field party considered it very likely that acid rain is contributing to a complex, along with the historical drought events and successional phenomena. Such a complex is operating most strongly on the shallow-rooted species (spruce) growing on relatively shallow organic soils, especially, though not exclusively, at high elevations.

Aluminum and calcium imbalances in the soil brought about by acid deposition, noted as major factors in causing forest decline elsewhere, are not yet likely in themselves to be the main cause of decline, but may become increasingly important.

In our project, monitoring of input, uptake, internal transfers, output and productivity continue at our intensive nutrient cycling site for the purposes of evaluating the effects of acid precipitation in spruce forest ecosystems.

Static soil sampling involving a 20-year interval was completed. These data will be used in conjunction with more recent dynamic sampling to estimate changes in these forest soil profiles.

(A.G. Gordon)

Productivity and Nutrient Cycling in Spruce Forest Ecosystems

If anticipated demands for forest products are to be met, the discipline of forestry must become more and more exact in its application of forest management practices. The accurate prediction of yield, site stability or deterioration, competition, and permissible rotation ages, under various forms of management, will be increasingly important. Given the widely accepted predictions of timber shortage and the increasing unregenerated backlog area, it is paramount to ensure that Forest Management Agreement forests as well as non-agreement forests produce up to expectations, rather than decline. To maintain and even increase productivity, only the most scientifically exact forms of management will ultimately suffice.

Why study nutrient cycling? Nutrient budgets are definitions of principal biological and geophysical constraints to productivity in forest sites. Nutrient cycles are the processes through which these operate. Biomass and productivity quantify and define rates for the end-products.

From nutrient budgets we can determine the amount of nutrient capital exported with any form of harvesting; based on capital reserves and cycling rates, we can obtain estimates of replacement times. Since harvesting alone consitutes the principal nutrient export from an ecosystem, we can obtain information as to which sites are particularly vulnerable to full-tree harvesting, or to certain kinds of site preparation. These studies are not easy to undertake, and generally extend through at least a short weather cycle. They involve the measurement of some simple and some complex parameters. The data sets are very valuable, and can be developed to a high level of predictive power.

The measurement of a number of biomass, productivity and nutrient cycling parameters has been completed. Others are ongoing. Among these are input and flux studies of forest waters: rainfall, snowfall, throughfall, stemflow, and soil profile water runoff, through the use of soil porous cups, lysimeters, surface funnels and chemical analyses. These studies also include measurement of sulphate and nitrate components to determine the long-term effects of acid precipitation.

Another study concerns the productivity of feather moss under black spruce stands and looks at how the cycling of nutrients in the ground flora affects the uptake of nutrients by overstory black spruce. Sampling is completed; chemical analysis is under way.

Of particular importance is a study to develop predictive models for white spruce on a site array. This will facilitate more efficient future sampling of spruce for both wild and plantation-grown trees. Small-tree sampling is completed; further large-tree data is required for various sites. Specific gravity measurements are under way.

Soil sampling and analyses of chemical and physical properties of boreal mixedwood white spruce plots in the Dog River area, Thunder Bay District, were also completed.

(A.G. Gordon)

TABLE 7 Growth and performance at Flesherton of five Euramerican clones ranked according to size in 1983, at 13 years after planting

Clonal* Code	Rank (size) 78	Rank (size) 83	Dbh 78	Dbh 83	MAI 71-83	MPI 79-83	Annual Incr. 82	Annual Incr. 83	% Growth 83/82	Rank (growth) 82	Rank (growth) 83	% Surviving 1983	% Healthy 1983
						Imperial units (inch)							
DN-2	1	1	7.92	11.45	.88	.72	.79	.45	57	5	4(a)	100	75
DN-6	2	2	7.47	11.31	.87	.77	.90	.51	56	2	1	"	100
DN-16	3	3	7.10	10.70	.82	.72	.81	.45	55	4	4(b)	"	100
DN-19	8	4	6.85	10.51	.81	.73	.92	.45	49	1	4(c)	"	100
DN-9	7	5	6.93	10.23	.79	.66	.70	.50	71	7	2	"	100
						Metric units (cm)							
DN-2	1	1	20.1	29.1	.2	1.8	2.0	1.1	57	5	4(a)	100	75
DN-6	2	2	19.1	28.7	.2	1.9	2.3	1.3	56	2	1	"	100
DN-16	3	3	18.0	27.2	.1	1.8	2.1	1.1	55	4	4(b)	"	100
DN-19	8	4	17.4	26.7	.1	1.9	2.3	1.1	49	1	4(c)	"	100
DN-9	7	5	17.6	26.0	.0	1.7	1.8	1.3	71	7	2	"	100

* Populus x euramericana cv:

DN-2 = 'Baden 431'
DN-6 = 'Grandis'
DN-16 = 'Regenerata Batard'
DN-19 = 'Blanc du Poitou'
DN-9 = 'Loens'

Sensitivity of Species and Cultivars to General and Seasonal Climatic Conditions

With the increasing availability of new varieties, selections and species for intensive forest management, there is a growing need for short-term assessment of their inherent potential in relation to environmental influences and cultural treatments. There is now sufficient indication that dendrometer tapes can be used effectively for this purpose by providing diameter growth information, on a current basis, for individual trees, clones and stands.

Peter Jaciw's growth measurements make it possible to evaluate the environmental sensitivity and stability of species, clones and stands.

To evaluate performance of 35 Euramerican poplar hybrids established at Flesherton, Ontario, at 500 m ASL, dendrometer measurements of 140 sample trees were continued at regular intervals. In comparison to the previous years, diameter growth in 1983 declined substantially and consistently for all clones. The reduction was especially large relative to the preceding year (1982), indicating appreciable differences in growing conditions during the two seasons. The average decline of 1983 annual growth as compared to 1982 was about 50%, ranging from 14% to 69% for the individual clones. The seasonal

growth pattern showed that for 74% of the cultivars the rate of decline was particularly rapid during the period from May 27 to August 5; however, 26% of the varieties showed no such trend, remaining fairly stable in their performance during the above-mentioned period.

The general growth reduction of the Euramerican poplar at Flesherton in 1983 was attributed mainly to the prevailing weather conditions, and particularly to high temperatures and below-average precipitation during the most essential part of the growing season. According to atmospheric records for the Flesherton area, the average precipitation in June and July, 1983, was only 61% relative to the same period in 1982, while the average temperature was higher by 12%. As the weather conditions in June and July, 1984, approximated those of 1982, there followed again an appreciable and consistent improvement in diameter growth of all clones.

The uncommon meteorological fluctuations during the three consecutive years from 1982-1984 provided an opportunity for a critical comparison of the environmental sensitivity and stability of the Euramerican poplar cultivars growing under the characteristically variable and exacting conditions of the Dundalk Uplands. Considering the overall performance of the tested poplar varieties, there is now sufficient information for evaluation of the suitability of a number of cultivars for growing in the general Flesherton area and under similar conditions elsewhere in Ontario. The following table (Table 7) shows some selected statistics for five such potential clones, ranked according to size attained by 1983.

(P. Jaciw)

Red Pine Growth Studies

Red pine (Pinus resinosa) is an actively growing species that has been planted extensively throughout Eastern North America, mostly for pulp. This tree displays a remarkable ability to survive extremes of deep, sandy soils. Although a subhumid territory such as Southern Ontario is characterized by abundant precipitation, ecological influences on forest growth vary greatly because of the infiltration rates specific to different soils.

Environmental influences on growth are of considerable ecological significance, as some species of great economic importance may be grown over a wide range of sites. It is important to identify the major atmospheric processes that control growth, as well as the extent to which they can be manipulated through forestry practices. Within this framework, a large set of data on diameter growth, covering 11 years of bi-weekly measurements with dendrometer tapes, was analyzed in conjunction with daily records of temperature, solar radiation, relative humidity and wind. Significant derived variables were also analyzed, such as degree days, corn heat units and potential evapotranspiration according to the Penman model.

Preliminary analysis of this data has shown that diameter growth in the initial phase appears to be triggered by a thermal threshold of 6-8°C in air, and considerably less in the forest floor. Thereafter, for a short period, in some years less than two weeks, the magnitude of current growth is tied to the amount of heat received. This phase appears to end when the temperature reaches 18-20°C and is increasing.

In most years the soil has plenty of water during this phase; spring precipitation is normally abundant. However, a shortage of precipitation in this phase appears to affect growth only slightly, if at all.

After the peak of growth has been reached, normally in late June, a new phase of growth begins. Though the trees still have considerable growth potential, the recorded growth depends strongly on the regularity of rains. In years with marked drought spells in late July or August, growth almost ceases, only to recover again--normally at a lower level--when the drought spell has ended. Growth appears to cease when a thermal threshold of about 5°C is reached.

The preliminary analysis presented above represents a coarse assessment of the influence of weather on growth. The application of multivariate statistics to this data, using fast microcomputers, should yield much additional information on how to quantify the separate influences on growth. A comprehensive analysis of the impact of environment on the growth of red pine must also reflect the effect of the soil water deficit; such a model is now under development.

(C. Papadopol and P. Jaciw)

Forest Ecosystem Classification

Foresters manage "stands" that include the trees, the lower vegetation and the soil. Nowadays the name "ecosystem" is used frequently for this combination of stand features. If management knowledge and experience are to be organized, communicated, and used effectively, a practical, clear method for classifying forest ecosystems is needed. Then each manager knows what the others are talking or writing about.

A program to develop a forest ecosystem classification (FEC) for the Clay Belt part of the Northern Region was started in 1979, with major data collection and initial analysis being conducted since 1980. The earlier work was reported in previous annual reports. In 1982, the design of the classification was completed, to serve primarily the harvesting and regeneration phases of management. Fourteen classes called Operational Groups were established and an allocation key was developed. This simple key, based on easily recognized features of vegetation and soil, is the tool with which any worker in the field can quickly allocate any forest stand to its appropriate Operational Group.

During the field testing of the key, further data were collected to verify the range and frequency of occurrence of soil and vegetation conditions within each Operational Group. Work was started toward developing techniques for recognizing Operational Groups on aerial photographs and for mapping their occurrence in the landscape. A manuscript of a field guide to forest ecosystem classification in the Clay Belt was prepared for publication, and field courses were given to management staff (both OMNR and industry) to ensure the full understanding and use of the classification.

This program is conducted cooperatively with Northern Region staff and staff from Agriculture Canada and Environment Canada, and is partly funded from the federal/provincial Forest Management Subsidiary Agreement.

(G. Pierpoint)

Georeferencing Data-Base

During 1982/83, the Double-Bounding procedure already developed as a replacement for, and an improvement over, simple translation and rotation of raw table coordinates into Map Projection coordinates was incorporated into the Data-Capture procedure in the Formagain system. It has been implemented only for OBM sheets (Ontario Base Maps in 6° UTM). This permits the raw table coordinates to be converted into 6° UTM coordinates during the digitization of each map sheet.

Attempts were made to apply such a conversion to previously digitized files where the points had been stored as raw table coordinates. It was discovered that interruptions and restarts during digitization had often corrupted portions of some or all of the six interrelated data files associated with each map sheet. Many kinds of corruption had clear, obvious solutions; these were corrected in the error-detection program. However, other kinds could not be resolved without recourse to graphics editing where the best optional solution would be chosen after display and examination; these errors were listed for resolution by graphics editing. Error detection is still ongoing.

A pair of programs was written to provide unique names for the sets of files related to any map sheet or any portion of any map sheet. The names were character strings that were coded or decoded using base 62 arithmetic. Previously, files had been named according to the township they came from, so that large numbers of files shared the same name and were distinguished only by being stored in different directories.

(F.L. Raymond)

PAPERS AND POSTERS PRESENTED

Anderson, H.W. Regenerating yellow birch with prescribed fire. SAF Convention, Fire Working Group, Cincinnati, Ohio. 1982.

Anderson, H.W. and L. Zsuffa. Genetically improved forest biomass energy production. Fourth Bioenergy R & D Seminar, National Research Council (ENFOR), Winnipeg, Manitoba. 1982.

Anderson, H.W. and L. Zsuffa. Hybrid poplar energy plantations in Ontario. ENERGO '83 Conference, Toronto, Ontario. 6-9 March 1983.

Anderson, H.W. and L. Zsuffa. Biomass growth and qualities of hybrid poplar. 2nd Canadian Waferboard Symposium, Ottawa, Ontario. 1-3 June 1982.

C.P. Chen, and D.N. Roy. Internal biomass characteristics for efficient energy conversion. Joint Workshop of IEA/FE PG 'B', 'C', and 'D', Uppsala, Sweden. 11 June 1984.

Beckwith, A.F., P. Roebbelen and S. Pessione. Variable density growth and yield of managed jack pine plantations. Jack Pine Symposium, Timmins, Ontario. 18-20 October 1983.

Danzmann, R.G. and G.P. Buchert. Isozyme variability in central Ontario Jack Pine. 28th Northeastern Forest Tree Improvement Conference, Durham, New Hampshire. 7-9 July 1982.

Buchert, G.P. Winter hardiness assessment in seedlings of pure and hybrid pitch pine. 28th Northeastern Forest Tree Improvement Conference, Durham, New Hampshire. 7-9 July 1982.

Burger, D. Aspects of Forestry Research. Sigma Xi Seminar. Delta States Research Center, USDA Southern Forest Experiment Station, Leyland, Mississippi, 16 March, 1984.

Burger, D. Site Regions in the Service of Management. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Burger, D. Ontario Site Regions in a continental context. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Colombo, S.J. Container and bare-root nursery stock research directions. Central Region Forests Technical Committee Meeting, Aurora, Ontario. 1 December 1982.

Colombo, S.J. Winter damage to container seedlings: Consequences and prevention. OMNR Nurserymen's Meeting, Thunder Bay, Ontario. 7-11 June 1982.

Colombo, S.J. Acclimatizing and overwintering spruce container stock. OMNR Nurserymen's Meeting, Kemptville, Ontario. 13-17 June 1983.

Colombo, S.J. Overwintering container seedlings. Meeting of Northwestern Region Container Stock Growers, Dryden, Ontario. 29-31 August 1983.

Colombo, S.J. Improving the quality of overwintered container stock using Extended Greenhouse Culture. OMNR Nurserymen's Meeting, Swastika Forest Station, Ontario. 18-21 June 1984.

Colombo, S.J. Interpreting the significance of plant moisture stress by means of the pressure-volume technique. OMNR Nurserymen's Meeting, Swastika Forest Station, Ontario. 18-21 June 1984.

Colombo, S.J. Overwintering practices for container stock. Meeting of the North Central and Northwestern Regions Container Stock Growers, Thunder Bay, Ontario. 13 September 1984.

Colombo, S.J. Extended Greenhouse Culture: An update. Meeting of the Northern Region Container Stock Growers, Ramore, Ontario. 22-23 November 1984.

Colombo, S.J. Can plantation performance be predicted using the pressure bomb? COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Colombo, S.J. Overwintered spruce container stock: High quality through cultural techniques. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Colombo, S.J. Frost hardiness measurement techniques. Forest Nursery Association of British Columbia, Annual Meeting, Duncan, British Colombia. 23-26 September 1985.

Drysdale, D., D. Morgan, and L. Zsuffa. 1982. Energy plantations - The present situation and plans for 1983-1988. Joint PG'B'-PG'C' Meeting, Oslo, Norway. 11 October 1982.

Farintosh, L. Tamarack superior tree selection criteria. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Fayle, D.C.F. Difference between stem and root thickening at their junction in red pine. IUFRO conference on Tree root systems and their mycorrhizas, Edinburgh and Canterbury, UK. 12-18 September 1982.

Fayle, D.C.F. Root growth and development in relation to coppice management. IEA/FE PG'B' Meeting, Oslo, Norway. 11-15 October 1982.

Glerum, C. Frost hardiness and dormancy in conifers. North-eastern Area Nurserymen's Conference, Halifax, Nova Scotia. 1982.

Glerum, C. Stock production research program: Overview. OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Glerum, C. Root pruning at time of lifting. OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Glerum, C. Frost hardiness of coniferous seedlings. Principles and applications. Evaluating Seedling Quality Workshop, Oregon State University, Corvallis, Oregon. 16-18 October 1984.

Gordon, A.G. Nutrient cycling dynamics in differing spruce and mixedwood ecosystems in Ontario and the effects of nutrient removal through harvesting. International Symposium on the Dynamics of the Boreal Forest Ecosystems: Future Research and Management Requirements. Lakehead University, Thunder Bay, Ontario. 23-26 August 1982.

Gordon, A.G. Genetics, genecology and tree improvement of spruce in 1981 and 1982, Sault Ste. Marie, Ontario. 19th Meeting Canadian Tree Improvement Association, Toronto, Ontario. 22-26 August 1983.

Gordon, A.G. Spruce improvement through intra- and interspecific breeding. Poster Session, 19th Meeting Canadian Tree Improvement Association, Toronto, Ontario. 22-26 August 1983. (poster)

Gordon, A.G. Spruce genecology: genotype x environment interaction. Canadian Institute of Forestry Meeting at OTIFBI, Maple, Ontario. 26 October 1983.

Gordon, A.G. Budworm! What about the forest? Society of American Foresters, Region VI, 2nd Tech. Conference, Burlington, VT. 24-26 April 1984.

Gordon, A.G. Spruce improvement through intra- and interspecific breeding. Poster Session, COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Gordon, A.G. Stand dynamics and the budworm. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Ho, R.H., A.Y. Raj, and L. Zsuffa. Poplar plants through another culture. 28th Northeastern Forest Tree Improvement Conference, Durham, New Hampshire. 6-7 June 1982.

Ho, R.H. Wood energy plantations: the state of the art and the potential of biotechnology in forest tree improvement. IEA/FE PG'B' Meeting, Quebec City, Quebec. 18-21 April 1983.

Ho, R.H. Research on seed-cone receptivity, cone induction, and in vitro culture. 19th meeting Canadian Tree Improvement Association, Part 1, Toronto, Ontario. 22-26 August 1983.

Ho, R.H. Production of important hybrids from sexually incompatible species by ovule and embryo culture, and protoplast fusion. IEA/FE PG'B' Meeting, Uppsala, Sweden. 4-14 June 1984.

Ho, R.H., and L. Zsuffa. Biotechnology in breeding for biomass production. 1st Bioenergex Specialists Meeting, Waterloo, Ontario. 15 October 1984.

Ho, R.H. Cone induction in white and Norway spruce. Canadian Tree Improvement Association Meeting, Quebec City, Quebec. 20-22 August 1985.

Ho, R.H., and A.Y. Raj. In vitro propagation of some conifers by cotyledon and epicotyl culture. Canadian Tree Improvement Association Meeting, Quebec City, Quebec. 20-22 August 1985.

Ho, R.H. Micropropagation of America Elm. Canadian Tree Improvement Association Meeting, Quebec City, Quebec. 20-22 August 1985.

Ho, R.H. Cone induction and in vitro culture in some forest tree species. Canadian Tree Improvement Association Meeting, Quebec City, Quebec. 20-22 August 1985.

Hutchison, R.E. Lifting, storage and holding period of "bare-root" Jack pine. COJFRC Jack Pine Symposium, Timmins, Ontario. 18-20 October 1983.

Hutchison, R.E. Root soaking at time of planting. Ontario Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Jaciw, P. Selected references on treatment, disosal and application of urban, industrial and agricultural wastes. IEA/FE PG'B' Meeting, Oslo, Norway. 11-15 October 1982.

Jaciw, P. Hardwood thinning. COJFRC Information Session, Kortright Conservation Centre, Kleinburg, Ontario. 23-25 February 1982. (poster)

Jaciw, P. Short rotation poplar - stock types and site preparation. COJFRC Information Session, Kortright Conservation Centre, Kleinburg, Ontario. 23-25 February 1982. (poster)

Jaciw, P. Monitoring growth with dendrometers. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Jaciw, P. Stand establishment. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Jaciw, P. and C.S. Papadopol. Influences of seasonal precipitation and temperature on diameter growth patterns of pruned red pine. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Jaciw, P. and C.S. Papadopol. Influences of seasonal precipitation and temperature on diameter growth of red pine by spacing. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

MacDonald, G.B. Mixedwood dynamics and yield. OTIFBI Forest Productivity Workshop, Maple, Ontario. 7 December 1982.

MacDonald, G.B. Balsam fir management potential. North Central Region Technical Information Session, Thunder Bay, Ontario. 13 April 1983.

MacDonald, G.B. New formulae for accurate volume predictions. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

McClain, K.M. Conditioning planting stock: should we be concerned? COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

McClain, K.M. Determining seedling damage. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Papadopol, C.S. The intensive poplar culture in eastern Romania. University of Toronto, Faculty of Forestry, Toronto, Ontario. 6 April 1982.

Papadopol, C.S. Some effects of water on the accumulation of poplar biomass and energy budget. North American Poplar Council, 17th Annual Meeting, Rhinelander, Wisconsin. 20-22 July 1982.

Papadopol, C.S. and C.R. Silversides. Stand establishment of fast growing species for energy plantations. Workshop of the IEA/FE PG'B' Meeting, Vettre, Norway. 11 October 1982.

Papadopol, C.S. Evapotranspiration and its importance in forestry. University of Toronto, Faculty of Forestry, Toronto, Ontario. 12 March 1984.

Papadopol, C.S. The renovation of waste water combined with intensive silviculture. American Society of Agricultural Engineers, New Orleans, Louisiana. Winter 1984.

Papadopol, C.S. An integrated irrigation system for forest nurseries in Ontario. American Society of Agricultural Engineers, New Orleans, Louisiana. Winter 1984.

Papadopol, C.S. and J.D. Nolan. The potential of tree plantation technology in the land treatment of waste water from food processing industry. 5th International Symposium on Agricultural Wastes. American Society of Agricultural Engineers, Chicago, Illinois. 16-17 December 1985.

Paterson, J. and C. Glerum. Jack pine stock types compared on two moisture regimes. COJFRC Jack Pine Symposium, Timmins, Ontario. 18-20 October 1983. (poster)

Paterson, J. and C. Glerum. Comparison of spring-sown and overwintered Japanese paperpot jack pine. COJFRC Jack Pine Symposium, Timmins, Ontario. 18-20 October 1983. (poster)

Paterson, J. Nursery needle length indicates field growth potential. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Paterson, J. Multiple leadering - is it a field problem? OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Paterson, J. Culling practices. OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Racey, G.D. and C. Glerum. Lifting, storage and extended planting season of jack pine. COJFRC Jack Pine Symposium, Timmins, Ontario. 18-20 October 1983. (poster)

Racey, G.D. Physical approaches towards readiness for lifting. OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984. (poster)

Racey, G.D. Readiness for overwinter storage. OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Racey, G.D. Root volume or root area index? OMNR Nurserymen's Meeting, Swastika, Ontario. 18-21 June 1984.

Racey, G.D. and C. Clerum. Readiness for lifting for storage. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Racey, G.D., R. Hutchison, and C. Glerum. Twenty-six ways to a better stand. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Racey, G.D. Physical approaches towards readiness for lifting. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Raj, A.Y., R.H. Ho, and L. Zsuffa. In vitro propagation of forest trees by tissue culture. 28th Northeastern Forest Tree Improvement Conference, Durham, New Hampshire. 6-9 June 1982.

Stroempl, G. Thinning clumps of hardwood stump sprouts. COJFRC Information Session, Kortright Conservation Centre, Kleinburg, Ontario. 23-25 February 1982.

Stroempl, G. Layout of coniferous plantations to improve stand stability against wind damage. COJFRC Information Session, Kortright Conservation Centre, Kleinburg, Ontario. 23-25 February 1982.

Stroempl, G. Thinning techniques and underplanting of red oak in hardwood stands. Central Region Forest Technical Committee Meeting, Aurora, Ontario. 18 December 1984.

Stroempl, G. Grading red oak nursery stock. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Stroempl, G. Planting depth to improve field survival of nursery stock. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985.

Weingartner, D. Thinning aspen in the boreal mixedwood forest. COJFRC Information Session, Geneva Park, Orillia, Ontario. 25-27 February 1985. (poster)

Zsuffa, L. and D. Morgan. The use of Populus and Salix biomass for

energy -- a survey of International Poplar Commission countries. 2nd Meeting Ad Hoc Committee on Biomass Production Systems in Salicaceae, International Poplar Commission, Casale Monferrato, Italy. 6-10 September 1982.

Zsuffa, L. Biomass production for energy in Canada. 2nd meeting Second Session of the Ad Hoc Committee on Biomass Production Systems in Salicaceae, International Poplar Commission, Casale Monferrato, Italy. 6-10 September 1982.

COJFRC INFORMATION SESSION 1985

"Forest Research--Who Needs It?" was the title of the 8th annual COJFRC Information Session, sponsored this year by OTIFBI and held on 25-27 February at Geneva Park.

The question was resoundingly answered: "We do." Many attendees acclaimed it the most successful information session to date. The results of the questionnaire distributed afterwards indicated that most achieved or exceeded their expectations in terms of the ideas presented and the opportunity to communicate with the OTIFBI scientists.

The 119 attendees (not counting staff from OTIFBI) included 55 MNR field staff, nine MNR main office staff, 20 CFS staff, 16 academics, 11 private sector representatives and eight from other ministries and federal departments.

The 1 1/2-day session comprised an evening icebreaker with a guest speaker; 14 scientific papers; two information papers (from the Ontario Tree Improvement Council and from the the Fast Growing Hardwoods Group); and 60 posters and information displays. A special evening session and three 45-minute coffee breaks were scheduled for talking to the scientists and viewing the displays.

UNIVERSITY INVOLVEMENTS

Anderson, H.W.
Adjunct Professor of Silviculture, Faculty of Forestry, University of Toronto. On advisory committee for five graduate students (four M.Sc.F., one Ph.D.). He has lectured on hybrid poplar wood quality, breeding for quality wood, hardwood silviculture, hardwood stand dynamics, and tree physiology. He is the Chairman of the curriculum review sub-committee on the "Biological Basis of Forestry", Faculty of Forestry, University of Toronto.

Beckwith, A.F.
On M.Sc.F. committee for Peter Newton, Faculty of Forestry, University of Toronto.

Burger, D.
Seminar "Land classification" for Faculty of Forestry, University of Toronto, 16 November 1983.

Fayle, D.C.F.
Gave lectures at School of Forestry, Lakehead University (two on silviculture); Faculty of Forestry (two on forest research); and Faculty of Architecture and Landscape Architecture (one on tree roots); York University (seminar on tree roots); and Department of Ecophysiology, Swedish University of Agricultural Sciences, Uppsala. Supervised one Master's student and served on two M.Sc.F. and three Ph.D. committees at University of Toronto, and one Ph.D. committee at University of Guelph.

At the invitation of the Department of Ecophysiology, Swedish University of Agricultural Sciences, Uppsala, Sweden, he investigated and discussed root development of irrigated/ fertilized Scots pine.

Glerum, C.
Presented two lectures (31 January and 8 February 1983) to fourth-year students of the Faculty of Forestry, University of Toronto, one in physiology on frost hardiness and another in soil management on planting stock quality. Also a Supervisory Committee Member on M.Sc.F. program of Raymond Folk at the Faculty of Forestry, University of Toronto, starting October 1984.

Gordon, A.G.
Appointment (in July 1983) to adjunct professor of genecology at the Faculty of Forestry, University of Toronto. Lectured on species variation and provenance testing at the Faculty of Forestry, University of Toronto, 17 October 1983. Lectured on the structure, functioning and nutrient cycling dynamics of white, red and black spruce forest ecosystems in the northeast: their importance in nutrient removal through harvesting, at the University of Alberta and at the Northern Forestry Centre, Canadian Forestry Service, Alberta; and on some relationships within the genus Picea and their evolutionary implications, at the Departments of Forest, Science and Botany, University of Alberta.

MacDonald, G.B.
M.Sc.F. Committee Member, Lakehead University, School of Forestry, September 1984 - October 1985.

McClain, K.M.
In 1985, presented two lectures to fourth-year silviculture students at Lakehead University on the importance of physiology in forest regeneration.

Zsuffa, L.
Spring of 1982, led and lectured FOR 1012Y "Forest Genetics" Course at the Faculty of Forestry, University of Toronto. Fall of 1982, led and lectured FOR 460F, "Forest Genetics and Tree Breeding" course at the Faculty of Forestry, University of Toronto. Supervisor on Student Committee of two Ph.D. graduates, and a Supervisory Committee Member for three M.Sc.F. and one Ph.D. graduates.

COMMITTEES

Anderson, H.W.
Algonquin Park Hardwood Manual Committee.

Gordon, A.G.
Special advisor on the genus Picea (spruce) to the Arnold Arboretum of Harvard University, Highland and Durand-Eastman Parks Arboreta, Munro County Parks Department, Rochester, New York. 1984: Advisor on U.S. Forest Service, Institute of Northern Forestry, Fairbanks, Alaska. 1985: Appointment to U.S. Forest Service project review/grant proposal referee committee for all proposals funded by U.S. Forest Service on acid precipitation and spruce-fir forest research. 1984-85: Participant in survey on the impact of the long-range transport of air pollutants (LRTAP) on forests in Canada.

Jaciw, P.
Research contact with Panel of Advisory Committee on Technology Innovation, Board of Science and Technology for International Development. (Subject: Robinia pseudoacacia)

Roebbelen, P. and A.P. Beckwith.
Committee on Sample Plot Working Group for developing a province-wide catalogue of sample plots.

Skeates, D.A.
OMNR Management Committee on Container Transplants.

Zsuffa, L.
Member of the Tree Improvement Steering Committee, the Hybrid Poplar Steering Committee, and the COJFRC Committee. Chairman of the COJFRC Tree Improvement Working Group and the IUFRO Working Group No. S2.02-00 - Poplar Provenances. Chaired the Planning Group 'B' - Biomass Growth and Production, FE/IEA, and organized meeting PG'B'-9 in Gent, Belgium, 6-9 April 1982, and meeting PG'B'-10, Oslo, Norway, 11-15 October 1982. Chaired the International Poplar Commission (IPC) Ad-hoc Committee for Biomass Production Systems in Salicaceae, and organized a meeting at Casale, Monferrato, Italy, 6-7 September 1982. Secretary-Treasurer of the Poplar Council of Canada and the Co-Chairman of both the IUFRO Working Group No. S2.03.-7 - Poplar Breeding and the IUFRO Program Group No. P1.09.00 - Integrated Research of Biomass for Energy.

EXTERNAL CONTRACTS

Payle, D.C.F.
Effects of simulated acid rain on germination and growth of yellow birch, white pine and eastern white cedar. Prof. D.V. Love for R. Koppenaal (graduate student), Faculty of Forestry, University of Toronto.

Papadopol, C.S.
J. Vlcek and E. Cheung: Video Imaging and Image Analysis in Monitoring progress of Melampsora Infection on Poplar Leaves.

Pierpoint, G.
Reconnaissance Soil Survey of Chapleau and Foleyet Map Sheets, Professor L. Evans, Ontario Institute of Pedology, University of Guelph. Cochrane Forest Soil Survey, Ecological Services for Planning Ltd., Guelph. Soil Survey of the Hearst area, MacLaren Plansearch Inc., Toronto. Forest Stand Structure and Dynamics, Professor T.J. Carleton, University of Toronto. Soil Nutrient Regime and Black Spruce Growth, Professor V.R. Timmer, University of Toronto. Soil Interpretation and Soil Training Program for Forest Land Management in Southern Ontario, Ontario Institute of Pedology, University of Guelph.

Skeates, D.A.
For 1985, acted as senior Canadian advisor to the ASEAN/Canada Forest Tree Seed Centre in Muak Lek, Thailand. Edited an ACFTSC newsletter for seed workers in the ASEAN forest community.

Zsuffa, L.
"Casual agents for new canker-type diseases symptoms on poplar clones," Dr. M. Hubbes, University of Toronto. "Disease survey in hybrid poplar plantations and nurseries in Ontario," Dr. M. Hubbes, University of Toronto. "Identification of the genetic base of blister resistance in white pine," Dr. M. Hubbes, University of Toronto. "Selection and gene-pool collection of forest tree species," Dr. J. Eckenwalder, University of Toronto. "Survey, collection and identification of Salix species and hybrids occurring in areas on sampling plots in Southern and Central Ontario," Dr. K. Roller. "Isoenzyme studies of poplar seedlings," O.P. Rajora, University of Toronto. "Poplar and jack pine insect survey," J. Bendell/R. Wetzler, University of Toronto. "Genetic variation in trembling

aspen," Dr. J. Hyun, Seoul National University. "A study of balsam poplar wood quality in Ontario," Dr. J. Balatinecz, University of Toronto. "Genetic variation of balsam poplar," K. Falusi, University of Toronto.

OTHER ACTIVITIES

Anderson, H.W.
Instructor, course on hardwood marking for OMNR at Kingston, Ontario.

Burger, D. and P. Ulig
Presented three one-hour sessions on "Land Classification" for an OMNR Lands and Waters Certificate Course at Geneva Park, 30 November 1983.

Gordon, A.G.
Swan Lake spruce genetics and tree improvement--"Weekend in the Woods." Faculty of Forestry, University of Toronto, 16 October 1982. (field tour)

Biomass and productivity, nutrient cycling effects of nutrient removals. Forest Productivity Workshop, OTIFBI, Maple, Ontario, 7 December 1982. (field tour)

Batchawana Picetum. Spruce genetics and tree improvement--Canadian Institute of Forestry Annual Meeting, Sault Ste. Marie, Ontario, 4 October 1983. (field tour)

Jaciw, P.
Assisted as advisor in a research project: Incremental seasonal growth patterns of cropping and non-cropping apple trees. Researcher: J.A. Erf, Department of Horticultural Science, University of Guelph.

Roebbelen, P. and P. Uelig
Instructors, relation of site to tree and stand productivity, as as part of a four-day seminar, "Forest Soils--Silviculture Workshop," for foresters and resource technicians from Central Region Districts.

VISITORS

In the past three years, there have been many visitors to the Institute from outside North America. They include visitors from Argentina, Belgium, Brazil, China, England, Finland, France, Hungary, Indonesia, Ireland, Israel, Italy, Kenya, Korea, Malaysia, New Zealand, Norway, the Philippines, Poland, Portugal, Spain, Sweden, Thailand, and Yugoslavia.

PUBLICATIONS

1982

ANDERSON, H.W. 1982. Regenerating yellow birch with prescribed fire. Proc. SAF Convention, Fire Working Group, Cincinnati, Ohio. pp. 168-172.

ANDERSON, H.W. and L. ZSUFFA. 1982. Biomass growth and qualities of hybrid poplar. Paper presented to: 2nd Canadian Waferboard Symposium, Ottawa, Ont., 1-3 June, 1982. 24 p.

ANDERSON, H.W. and L. ZSUFFA. 1982. Genetically improved forest biomass energy production. Proc. Fourth Bioenergy R & D Seminar, National Research Council (ENFOR), Winnipeg, Man. pp. 392-394.

BATES, D.N., (J.M BELISLE, B.H. CAMERON, L.J. EVANS, R.K. JONES,) G. PIERPOINT, and B. van den BROEK. 1982. Field manual for describing soils. 2nd edition. Ontario Institute of Pedology, University of Guelph, Publication No. 82-1.

COLOMBO, S.J. 1982. Winter damage to container seedlings: Consequences and prevention. In Proc. OMNR Nurserymen's Meeting, Thunder Bay, Ont., 7-11 June 1982. pp. 10-24.

COLOMBO, S.J., C. GLERUM and (D.P. WEBB). 1982. Bud development in black spruce container stock. OMNR Forest Res. Note No. 32. 5 p.

FORSLUND, R.R. 1982. A geometrical tree volume model based on the location of the centre of gravity of the bole. Can. J. For. Res. 12(2): 215-221.

GLERUM, C. 1982. Frost hardiness and dormancy in conifers. Proc. of Northeastern area nurserymen's conference, Halifax, N. S. Dept. Lands and Forests, Truro, N.S. pp. 37-46.

(GUINON, M.), J.V. HOOD and (W.J. LIBBY). 1982. A clonal study of intraspecific variability in radiata pine. Aust. For. Res. 12. pp. 191-201.

HO, R.H. 1982. Haploid plant culture in poplar. In Physiology and Genetics of Intensive Culture. B.A. Thieges (Ed.). Proc. 7th North American Forest Biology Workshop, University of Kentucky, Lexington, Kentucky. pp. 210-213.

HO, R.H. 1982. Research on seed-cone receptivity, seed production potential, cone induction and haploid plant culture. In Proc. 18th Meeting Can. Tree Improvement Assoc., Part 1. D.F.W. Pollard, D.G. Edwards, and D.W. Yeatman (Eds.). Duncan, B.C., 17-20 Aug. 1981. pp. 116-118.

HOOD, J.V. 1982. Spruce and larch genetics, Ontario Forest Research Centre, 1979-1980. In Proc. 18th Meeting Can. Tree Improvement Assoc., Part 1. D.F.W. Pollard, D.G. Edwards, and D.W. Yeatman (Eds.). Duncan, B.C., 17-20 Aug. 1981. pp. 119-120.

(JEGLUM, J.K., R. ARNUP, R.K. JONES), G. PIERPOINT (and G.M. WICKWARE). 1982. Forest ecosystem classification in Ontario's Clay Belt: a case study. In Artificial Regeneration of Conifers in the Upper Great Lakes Region. G.D. Mroz and J.F.Berner (Eds.). Proc. Michigan Technical University, Houghton, Michigan. pp. 111-128.

(KAMRA, S.K.) and D.A. SKEATES. 1982. Summary Report, Tech. Session 4: Factors affecting seed storage. In Proc. IUFRO Symp. Forest Tree Seed Storage,

Petawawa, Ont., Sept. 1980. pp. 219-220.

McCLAIN, K.M. 1982. Growth, nutrition and root development of Ontario tubelings, plugs and 3+0 bare-root black spruce. In Proc. Containerized Tree Seedling Symposium. J.B. Scarratt, C. Glerum and C.A. Plexman (Eds.). Environment Canada, Can. For. Serv. COJFRC Symp. Proc. 0-P-10. pp. 331-341.

McCLAIN, K.M. 1982. The question of extending the planting season. In Proc. OMNR Nurserymen's Meeting, Thunder Bay, Ont., 7-11 June 1982. 13 p.

McCLAIN, K.M. 1982. Seedbed spacing and nitrogen effects on nursery growth and post planting performance of white and black spruce. In Proc. OMNR Nurserymen's Meeting, Thunder Bay, Ont., 7-11 June 1982. 16 p.

MULLIN, R.E. and J.S. LUCAS. 1982. Overwinter storage tests of larch and tamarack. OMNR Nursery Note No. 76. 7 p.

MULLIN, R.E. and T.R. MYLAND. 1982. Tests of time of lifting, dipping, and containers for overwinter storage at Dryden Nursery. OMNR Nursery Note No. 77. 7 p.

PAPADOPOL, C.S. 1982. Some effects of water supply on the accumulation of poplar biomass and energy budget. In North American Poplar Council, 17th Annual Meeting, Rhinelander, Wisconsin, 20-22 July 1982. pp. 84-91.

SAUL, G.H. and L. ZSUFFA. 1982. Vegetative propagation of alder (Alnus glutinosa L.) by rooted cuttings. OMNR Forest Res. Note No. 33. 3 p.

(SCARRATT, J.B.), C. GLERUM (and C.A. PLEXMAN) (Eds.). 1982. Proc. Canadian Containerized Tree Seedling Symposium. Environment Canada, Can. For. Serv. COJFRC Symp. Proc. 0-P-10. 460 p.

SKEATES, D.A. 1982. Cone collection tower. OMNR Forest Res. Note No. 30. 4 p.

SKEATES, D.A., D.E. IRVING and L. PORCIER. 1982. Pilot studies of black spruce germinant transplants in northern Ontario. OMNR Nursery Note No. 79. 9 p.

vanBORRENDAM, W. and D.A. SKEATES. 1982. White spruce gene pool conservation in southern Ontario. OMNR Forest Res. Note No. 31. 4 p.

ZSUFFA, L. 1982. Biomass Production for Energy in Canada. Presented to the 2nd session of the Ad-Hoc Committee on Biomass Production Systems in Salicadeae, International Poplar Commission, FAO, Casale Monferrato, Italy, 6-10 Sept. 1982. FO:CIP:BS/82/2. 5 p.

ZSUFFA, L. and D. MORGAN. 1982. The use of Populus and Salix biomass for energy--a survey of International Poplar Commission countries. Presented to the Ad-Hoc Committee on Biomass Production Systems in Salicaceae, International Poplar Commission, Casale Monferrato, Italy, 6-10 Sept. 1982. FO:CIP:BS/82/2. 12 p.

1983

ANDERSON, H.W. 1983. High speed forestry in Ontario (or, how I learned to stop worrying and love a weed). In G.I.R.M.S., Vol. 14. Department of Geography, Sir Wilfrid Laurier University, July 1983. pp. 43-62.

ANDERSON, H.W. and L. ZSUFFA. 1983. Hybrid poplar energy plantations in Ontario. Proc. ENERGO '83, Ontario Ministry of Energy, Toronto, Ont. pp. 134-145.

ANDERSON, H.W., C.S. PAPADOPOL and L. ZSUFFA. 1983. Wood energy plantations in temperate climates. In Forest Ecology and Management--An International Journal. Elsevier. 42 p.

BECKWITH, A.F., P. ROEBBELEN and (V.G. SMITH). 1983. Red pine plantation growth and yield tables. OMNR Forest Res. Rep. No. 108. 110 p.

BUCHERT, G.P. 1983. Winter hardiness assessment in seedlings of pure and hybrid pitch pine. In Proc. 28th Northeastern Forest Tree Improvement Conf., R.T. Eckert (Ed.). Univ. of New Hampshire, Durham, N.H., 7-9 July 1982. pp. 94-101.

BURGER, D. 1983. Service report of consultancy in forest soils, Forest Research Institute, Yezin, Burma. FAO Contract No. DP/BUR/72/004-1/FO. July-Sept. 1982. Mimeo 24 p.

(DANZMANN, R.G.) and G.P. BUCHERT. 1983. Isozyme variability in central Ontario jack pine. In Proc. 28th Northeastern Forest Tree Improvement Conf., R.T. Eckert (Ed.). Univ. of New Hampshire, Durham, N.H., 7-9 July 1982. pp. 232-248.

DRYSDALE, D.P., D. MORGAN and L. ZSUFFA. 1983. Energy plantations--the present situation and plans for 1983-1988. In Proc. workshop held by IEA Forestry Energy Programme, Short Rotation Forest Biomass--Production Technology and Mechanization. Per Olov Nilsson and L. Zsuffa (Eds.). 11 Oct. 1982, Vettre, Norway. pp. 3-11.

FAYLE, D.C.F. 1983. Differences between stem and root thickening at their junction in red pine. Plant and Soil 71: 161-166.

FAYLE, D.C.F., D. MacIVER and C. BENTLEY. 1983. Computer graphing of annual ring widths during measurement. For. Chron. 59: 291-293.

GORDON, A.G. 1983. Nutrient cycling dynamics in differing spruce and mixedwood ecosystems in Ontario and the effects of nutrient removals through harvesting. In Resources and Dynamics of the Boreal Zone. R.W. Wein, R.R. Riewe and I.R. Methven (Eds.) Association of Canadian Universities for Northern Studies, Ottawa. pp. 97-118.

HO, R.H. 1983. Wood energy plantations: the state of art and the potential of biotechnology in forest tree improvement. IEA/FE PG'B', Report 1983: 2. 30 p.

HO, R.H., A.Y. RAJ and L. ZSUFFA. 1983. Poplar plants through anther culture. In Proc. 28th Northeastern Forest Tree Improvement Conf., R.T. Eckert (Ed.). Univ. of New Hampshire, Durham, N.H., 7-9 July 1982. pp. 294-300.

(JONES, R.K.), G. PIERPOINT, (G.M. WICKWARE and J.K. JEGLUM). 1983. A classification and ordination of forest ecosystems in the Great Clay Belt of northwestern Ontario. In Resources and Dynamics of the Boreal Zone. R.W. Wein, R.R. Riewe and I.R. Methven (Eds.). Proc. of conference held at Thunder Bay, Ont., Aug. 1982. Assoc. of Canadian Universities for Northern Studies, Ottawa.

(JONES, R.K.), G. PIERPOINT, (G.M. WICKWARE, J.K. JEGLUM, R.W. ARNUP and J.M. BOWLES). 1983. Field guide to forest ecosystem classification for the Clay Belt Site Region 3E. With Agriculture Canada and Environment Canada. 127 p.

N.B. $15 charge per copy to users other than universities, colleges or government institutions. Cheque or money order payable to The Treasurer of Ontario.

LARSSON, H.C. 1983. A silvicultural planting key for lowland sites in southern Ontario. For. Res. Info. Paper No. 103. 35 p.

MORGAN, D., (M. NEENAN) and L. ZSUFFA. (Eds.) 1983. Forest biomass energy and its potential. IEA/FE PG'B', Report 1983: 7.16 p.

MOSSELER, A.J. and (M. HUBBES). 1983. Erwinia spp. and a new canker disease of hybrid poplars in Ontario. Eur. J. For. Path. 13 (1983): 261-279.

MULLIN, R.E. 1983. A test of the polybin for frozen overwinter storage of red pine. U.S. For. Serv., Tree Planters' Notes 34(1): 3-6.

PAPADOPOL, C.S. and (C.R. SILVERSIDES). 1983. Stand establishment of fast growing species for energy plantations. In Short Rotation Forest Biomass--Production Technology and Mechanization. Per Olov Nilsson and Louis Zsuffa (Eds.). Proc. workshop held by IEA Forestry Energy Programme, Vettre, Norway, 11 Oct. 1982. Swedish Univ. of Agric. Sci., Dept. of Operational Efficiency, Internal Report No. 229. pp. 43-58.

RACEY, G.D., C. GLERUM and R.E. HUTCHISON. 1983. Effects of packaging on field performance of fall- and spring-lifted jack pine at Swastika Nursery. OMNR Nursery Note No. 88. 5 p.

RACEY, G.D., C. GLERUM and R.E. HUTCHISON. 1983. Cold and frozen overwinter storage of white cedar. OMNR Nursery Note No. 90.6 p.

RACEY, G.D., C. GLERUM and R.E. HUTCHISON. 1983. The practicality of top-root ratio in nursery stock characterization. For. Chron. 59: 240-243.

RACEY, G.D. and R.E. HUTCHISON. 1983. Overwinter storage of white pine at St. Williams Nursery. OMNR Nursery Note No. 86. 5 p.

RACEY, G.D. and R.E. HUTCHISON. 1983. Overwinter storage of Scotch pine at St. Williams Nursery. OMNR Nursery Note No. 87. 4 p.

RACEY, G.D. and R.E. HUTCHISON. 1983. A field test of the snow cache with 2+2 white spruce from Swastika Nursery. OMNR Nursery Note No. 89. 4 p.

RACEY, G.D. and R.E. HUTCHISON. 1983. Root soaking, plant moisture stress and second year field performance of three coniferous species. OMNR Nursery Note No. 91. 7 p.

RACEY, G.D. and R.E. HUTCHISON. 1983. A comparison of some spring holding options for red pine. OMNR Nursery Note No. 95. 5 p.

RACEY, G.D., R.E. HUTCHISON and C. GLERUM. 1983. A comparison of kraft bags and polybins for overwinter frozen storage of white spruce. OMNR Nursery Note No. 92. 4 p.

RACEY, G.D., R.E. HUTCHISON and C. GLERUM. 1983. A white pine age-class comparison with variations in site and planting methods. OMNR Nursery Note No. 93. 6 p.

RACEY, G.D. and E. RAITANEN. 1983. Seedling development as affected by fibre and straw mulching at Midhurst Nursery. OMNR Nursery Note No. 94. 5 p.

RAJ, A.Y. 1983. Application of tissue and anther culture methods in Populus breeding. XV

International Congress Genet. New Delhi, India. 12-21 Dec. 1983. Oxford and IBH Pub. Ca. New Delhi (Abstract). p. 424.

RAJ, A.Y., R.H. HO and L. ZSUFFA. 1983. In vitro propagation of forest trees by tissue culture. In Proc. 28th NortheasternForest Tree Improvement Conf., R.T. Eckert (Ed.). Univ. of New Hampshire, Durham, N.H., 7-9 July 1982. pp. 281-293.

SAUL, G.H. and L. ZSUFFA. 1983. The use of small scions and bareroot stock in grafting white pine. OMNR Forest Res. Note No. 34. 3 p.

SKEATES, D.A. 1983. Pregermination: A key to early vigour in artificial silvicultural systems. In Proc. Northeastern Nurserymen's Conf., Halifax, N.S., July 1982.

STROEMPL, G. 1983. Growth response of basswood and sugar maple to an intermediate cutting. OMNR Forest Res. Report No. 107. 19 p.

ZSUFFA, L. 1983. Forest biomass energy production for the North. In Alaska/Canada North--Neighbours in Science--34th Alaska Science Conference, Arctic Division--AAAS, Symposium on Towards Energy Self-Sufficiency in the North: Energy Conservation and Forest Biomass, Whitehorse, Yukon, 28 Sept.-1 Oct.1983. 12 p.

ZSUFFA, L. 1983. Genetics in intensive silviculture. Weyerhaeuser Lecture, University of Toronto, 17 Nov. 1983.

ZSUFFA, L. 1983. Aspects of short rotation forest farming in Canada. In Proc. Bereitstellung und Verwertung von Lignocellulosen - Entwicklunsstand und Perspektiven - Status - und Expertenseminar/Workshop (Workshop on Preparation and Utilization of Lignocelluloses-State of Development and Perspectives). Julich, W. Germany, 20-22 Nov. 1983. pp. 101-129.

ZSUFFA, L. and D. MORGAN. 1983. Forest biomass energy production --a five year retrospect of the work of Programme Group 'B'. IEA/FE PG'B', Report 1983: 6. 69 p.

1984

ANDERSON, H.W. and L. ZSUFFA. 1984. Genetically improved hardwoods as a potential energy source in Ontario. In Proc. Energex 84: The Global Energy Forum, Regina, Sask. p. 211-214.

ANDERSON, H.W. and L. ZSUFFA. 1984. Biomass growth and qualities of hybrid poplar. In Proc. 1982 Canadian Waferboard Symposium, Ottawa, Ont., 1-3 June, 1982. Forintek Canada Spec. Publ. SP508E. pp. 197-200.

ANDISON, D., P. ROEBBELEN and A.F. BECKWITH. 1984. Initial thinning in a semi-mature white and red pine stand. OMNR Forest Res. Note No. 35. 4 p.

BECKWITH, A.F., P. ROEBBELEN and S. PESSIONE. 1984. Variable-density growth and yield of managed jack pine plantations. Proc. COJFRC Jack Pine Symposium, Oct. 1983, pp. 145-156.

BECKWITH, A.F., P. ROEBBELEN and (V.G. SMITH). 1984. Manual of red pine plantation growth and yield tables. Abbreviated from OMNR Forest Res. Rep. No. 108. 56 p.

COLOMBO, S.J. 1984. Acclimatizing and overwintering spruce container stock. In Proc. Nurserymen's Meeting, G. Howard Ferguson Forest Station, Kemptville, Ont., 13-17 June 1983. pp. 79-81.

COLOMBO, S.J. 1984. Shoot morphology of winter-damaged black spruce container seedlings. OMNR Forest Res. Note No. 36. 3 p.

COLOMBO, S.J. and C. GLERUM. 1984. Winter injury to shoots as it affects root activity in black spruce container seedlings. Can. J. For. Res. 14: 31-32.

COLOMBO, S.J. and K.D. ODLUM. 1984. Bud development in the 1982-83 overwintered black spruce container seedling crop. OMNR Forest Res. Note No. 38. 4 p.

COLOMBO, S.J. and (W.A. SMITH). 1984. Delayed bud initiation in black spruce container seedlings due to accidental daylength extension. OMNR Forest Res. Note No. 37. 4 p.

COLOMBO, S.J., (D.P. WEBB) and C. GLERUM. 1984. Frost hardiness testing: An operational manual for use with extended greenhouse culture. OMNR Forest Res. Rep. No. 110. 14 p.

(DURYEA, M.L.) and K.M. McCLAIN. 1984. Altering seedling physiology to improve reforestation success. In Seedling Physiology and Reforestation Success. M.L. Duryea and G.N. Brown (Eds.). Martinus Nyhoff/Dr. W. Junk, publishers.

GORDON, A. 1984. Genetics, genecology and tree improvement of spruce in 1981 and 1982, Sault Ste. Marie, Ontario. In Proc. 19th Meeting Can. Tree Improvement Assoc., Part 1. Toronto, Ont., 22-26 Aug. 1983. pp. 94-97.

HO, R.H. 1984. Research on seed-cone receptivity, cone induction, and in vitro culture. In proc. 19th Meeting Can. Tree Improvement Assoc., Part 1. Toronto. Ont., 22-26 Aug. 1983. pp. 98-101.

HO, R.H. 1984. Seed-cone receptivity and seed production potential in white spruce. For. Ecol. Manag. 9: 161-171.

HO, R.H. 1984. Production of important hybrids from sexually incompatible species by ovule and embryo culture, and protoplast fusion. IEA-For. Energy PG'B'--Biomass Growth and Production PG'B' Mtg., Uppsala, Sweden. 18 p.

HO, R.H. and L. ZSUFFA. 1984. Biotechnology in breeding for biomass production. In Proc. 1st Bioenergy Specialists' Meeting on Biotechnology. S. Hasnain, J. Lamptey and M. Moo-Young (Eds.). Univ. of Waterloo, 14-17 Oct. 1984. pp. 70-82.

ODLUM K.D. and S.J. COLOMBO. 1984. A comparison of three anti-transpirants for reducing water loss in black spruce container seedlings. OMNR Nursery Note No. 110. 4 p.

PAPADOPOL, C.S. 1984. The atmospheric demand for evapotranspiration: a reliable means for irrigation rate calculation. Nurserymen's Meeting, G. Howard Ferguson Forest Station, Kemptville, Ont., 13-17 June 1983. pp. 85-97.

PAPADOPOL, C.S. 1984. An integrated irrigation system for forest nurseries in Ontario. ASAE Paper 84-2619. 23 p.

PAPADOPOL, C.S. 1984. The renovation of waste water combined with intensive silviculture. ASAE Paper 84-2647. 10 p.

PATERSON, J.M. and D.C.F. FAYLE. 1984. Early prediction of plantation performance for red pine. For. Chron. 60(6): 340-344.

RACEY, G.D, L. BOWDERY and C. GLERUM. 1984. Root volume for

characterization of nursery stock. OMNR Nursery Note No. 102. 6 p.

RACEY, G.D. and R.E. HUTCHISON. 1984. A field test of 3 red pine age-classes. OMNR Nursery Note No. 106. 5 p.

RACEY, G.D., R.E. HUTCHISON and C. GLERUM. 1984. Effect of extended cold storage after overwinter frozen storage of white pine and white spruce. OMNR Nursery Note No. 105. 5 p.

ROEBBELEN, P. and (V.G. SMITH). 1984. An investigation of product form. Can. J. For. Res. 14(6): 768-774.

(ROLLER, K.). 1984. A guide to the identification of poplar clones in Ontario. 112 p.

SKEATES, D.A. 1984. Ontario forest tree seed research and development 1981-83. In Proc. 19th Meeting Can. Tree Improvement Assoc., Part 1. Toronto, Ont., 22-26 Aug. 1983. pp. 111-114.

STROEMPL, G. 1984. Thinning clumps of northern hardwood stump sprouts to produce high quality timber. OMNR Forest Res. Information Paper No. 104. 27 p.

vanBORRENDAM, W. 1984. Identification of remnant white spruce in southern Ontario: a basis for gene conservation. OMNR Forest Res. Rep. No. 109. 20 p.

(WOOD, J.E.) and S.J. COLOMBO. 1984. A registry of containerized tree seedling reserch in Ontario: 1982-1983. Joint Report No. 4 of the Can. Forestry Service and OMNR. 23 p.

ZSUFFA, L. 1984. Breeding fast growing hardwoods and white pines at Ontario Tree Improvement and Forest Biomass Institute, Maple, Ont., during 1981-1983. In Proc. 19th Meeting Can. Tree Improvement Assoc., Part 1. Toronto, Ont., 22-26 Aug. 1983. pp. 115-118.

ZSUFFA, L. and D. MORGAN. 1984. Populus and Salix biomass for energy: a survey of International Poplar Commission countries. Unasylva 36 (1984/3): 31-33.

ZSUFFA, L., A. MOSSELER and Y. RAJ. 1984. Prospects for interspecific hybridization in willow for biomass production. In Ecology and Management of Forest Biomass Production Systems. K. Perttu (Ed.). Dept. Ecol. & Environ. Res., Swed. Univ. Agric. Sci., Report 15. pp. 261-281.

1985

ANDERSON, H.W., (J.J. BALATINECZ), C.P. CHEN, and (D.N. ROY). 1985. Internal biomass characteristics for efficient energy conversion. In Proc. Joint Workshop of IEA/FE, Programme Groups B, C, and D. D.J. Morgan, R.L. Gambles, L. Zsuffa and C.P. Mitchell (Eds.). Uppsala, Sweden, 11 June 1984. pp. 31-56.

COLOMBO, S.J. 1985. Improving the quality of overwintered container stock using extended greenhouse culture. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 28-35.

COLOMBO, S.J. 1985. Interpreting the significance of plant moisture stress by means of the pressure-volume technique. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 58-65.

COLOMBO, S.J., K.D. ODLUM and C. GLERUM. 1985. The use of the pressure bomb for assessing the quality of tree seedlings. In Proc. Workshop on Evapotranspiration, Irrigation and Plant Moisture Stress in Agriculture

and Forestry. D.C. MacIver and R.B. Street (Eds.). Kortright Centre for Conservation, Kleinburg, Ont., 2 Oct. 1984. pp. 66-72.

GLERUM, C. 1985. Stock production research program--overview. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 26-27.

GLERUM, C. 1985. Root pruning at time of lifting. Panel discussion. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. p. 55.

GLERUM, C. 1985. Frost hardiness of coniferous seedlings: principles and applications. In Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. M.L. Duryea (Ed.). proc. of workshop held at Forest Research Laboratory, Oregon State University, Corvallis, 16-18 Oct. 1984. pp. 107-123.

GLERUM, C. and J.M. PATERSON. 1985. A comparison between red pine seedlings and transplants five years after outplanting. OMNR Forest Res. Note no. 39. 4 p.

GORDON, A. 1985. Budworm! What about the forest? In Spruce-fir Management and Spruce Budworm. Proc. 2nd SAF Region VI Tech. Conf., Burlington, VT, 24-26 Apr. 1984. 29 p.

HO, R.H. 1985. Effect of repeated pollination upon filled seed in white spruce. Can. J. For. Res. 15: 1195-1197.

HO, R.H. and Y. RAJ. 1985. Haploid plant production through anther culture in poplars. For. Ecol. and Manage. 13:133-142.

HOOD, J.V. 1985. Development of genetic strategies for clonal forestry. In Clonal Forestry: Its Impact on Tree Improvement and Our Future Forests. Proc. 19th Meeting Can. Tree Improvement Assoc., Part 2. Toronto, Ont., 22-26 Aug. 1983. pp. 84-95.

HUTCHISON, R.E. 1985. Root soaking at time of planting. Panel discussion. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 55-57.

(KELLEHER, M.) and C.S. PAPADOPOL. 1985. Pre-feasibility study on expansion and upgrading of Port Dover sewage treatment plant. In Proc. Technology Transfer Conference, Part 2, Water Quality Research. Toronto, Ont., 11-12 Dec. 1985. Ont. Ministry of the Environment. pp. 198-225.

KIM, Y.T. and R.H. LEECH. 1985. Effects of climatic conditions on sap flow in sugar maple. For. Chron. 61(4): 303-307.

MacIVER, D.C. and (J. MASTERTON). 1985. Climatograms of Ontario. In Proc. Workshop on Evapotranspiration, Irrigation and Plant Moisture Stress in Agriculture and Forestry. D.C. MacIver and R.B. Street (Eds.). Kortright Centre for Conservation, Kleinburg, Ont., 2 Oct. 1984. pp. 49-55.

MacIVER, D.C. and (R.B. STREET) (Eds.). 1985. Proc. Workshop on Evapotranspiration, Irrigation and Plant Moisture Stress in Agriculture and Forestry. Kortright Centre for Conservation, Kleinburg, Ont., 2 Oct. 1984. 112 p.

MacIVER, D.C. and (R.B. STREET). 1985. Integrated irrigation management for forestry. In Proc. Workshop on Evapotanspiration, Irrigation and Plant Moisture Stress in Agriculture and Forestry. D.C. MacIver and R.B. Street (Eds.). Kortright

Centre for Conservation, Kleinburg, Ont., 2 Oct. 1984. pp. 41-48.

MORGAN, D.J., (R.L. GAMBLES), L. ZSUFFA and (C.P. MITCHELL) (Eds.).1985. Biomass characteristics for efficient energy conversion. Proc. Joint Workshop of IEA/FE, Programme Groups B, C, and D. Uppsala, Sweden, 11 June 1984. 103 p.

(MURRAY, G.) and D.A. SKEATES. 1985. Variation in height of white spruce provenances after 10 and 20 years in five field tests. In Proc. 29th Northeastern Forest Tree Improvement Conf., E.M. Demeritt (Ed.). Univ. of W. Va., Morgantown, W. Va. pp. 82-89.

ODLUM, K.D. and S.J. COLOMBO. 1985. Testing antitranspirants for nursery use. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 153-158.

PAPADOPOL, C.S. and (T.D. NOLAN). 1985. The potential of tree plantation technology in the land treatment of wastewater from food processing industry. In Agricultural Waste Utilization and Management, Proc. Fifth International Symposium on Agricultural Wastes. Chicago, Illinois, 16-17 Dec. 1985. ASAE Paper 13-85. pp. 411-417.

PATERSON, J.M. 1985. Multiple leadering--is it a field problem? In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 48-54.

PATERSON, J.M. 1985. Culling practices. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 66-68.

(PELKONEN, P.) and GLERUM, C. 1985. Poplar clonal variation in frost hardiness and electrical impedance during the Fall. For. Res. Rep. No. 112. 15 p.

PIERPOINT, G. 1985. Forest land classification: rationale and overview. In Proc. North Central Forest Soils Committee Symposium, Forest Land Classification: Experience, Problems, Perspectives. Madison, Wisconsin, 18-20 Mar. 1984. pp. 6-11.

RACEY, G.D. 1985. A comparison of planting stock characterization with root area index, volume and dry weight. For. Chron. 61(2): 64-65, 68-70.

RACEY, G.D. 1985. Readiness for overwinter storage. In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 36-47.

RACEY, G.D. 1985. Root volume or root area index? In Proc. Nurserymen's Meeting, Swastika Forest Station, 18-21 June 1984. pp. 69-71.

RACEY, G.D. 1985. Dissolved oxygen depletion by the roots of conifer seedlings during root soaking. OMNR Forest Res. Note No. 41. 4 p.

RACEY, G.D., C. GLERUM and R.E. HUTCHISON. 1985. Lifting and overwinter storage of white pine in southern Ontario. For. Chron. 61(6): 480-483.

RACEY, G.D., R.E. HUTCHISON and C. GLERUM. 1985. Performance of black spruce accelerated transplants after five years. OMNR Forest Res. Note No. 40. 4 p.

RACEY, G.D. and E. RAITANEN. 1985. The effects of fibramulch application rates on conifer seedbeds. OMNR Nursery Note No. 114. 4 p.

(SHAW, D.V.) and J.V. HOOD. 1985. Maximizing gain per effort by using clonal replicates in

genetic tests. Theor. Appl. Genet. (1985) 71: 392-399.

SKEATES, D.A. 1985. Improved seed efficiency through high density accelerated production of coniferous transplants. In Clonal Forestry: Its Impact on Tree Improvement and Our Future Forests. Proc. 19th Meeting Can. Tree Improvement Assoc., Part 2, Toronto, Ont., 22-26 Aug. 1983. pp. 207-212.

STROEMPL, G. 1985. Grading northern red oak planting stock. Tree Planters' Notes, U.S. Dept. of Agriculture, 36(1): 15-18.

WEINGARTNER, D.H. and (J.T. BASHAM). 1985. Variations in the growth and defect of aspen (Populus tremuloides Michx) clones in Northern Ontario. For. Res. Rep. No. 111. 26 p.

(WHITNEY, R.D.) and G.B. MacDONALD. 1985. Effects of root rot on the growth of balsam fir. Can. J. For. Res. 15(5): 890-895.

ZSUFFA, L. 1985. Concepts and experiences in clonal plantations of hardwoods. In Clonal Forestry: Its Impact on Tree Improvement and Our Future Forests. Proc. 19th Meeting Can. Tree Improvement Assoc., Part 2, Toronto, Ont., 22-26 Aug. 1983. pp. 12-25.

ZSUFFA, L., R.M. RAUTER and C. YEATMAN. (Eds.) 1985. Clonal Forestry: Its Impact on Tree Improvement and Our Future Forests. Proc. 19th Meeting Can. Tree Improvement Assoc., Part 2, Toronto, Ont., 22-26 Aug. 1983. 235 p.
N.B. Available from The Editor, C.T.I.A./A.C.A.A., Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario K0J 1J0.

Should you wish to receive copies of publications of the Ontario Tree Improvement and Forest Biomass Institute, please send your request to:

Technology Transfer
Ontario Tree Improvement and
Forest Biomass Institute
Ontario Ministry of Natural Resources
Maple, Ontario L0J 1E0
CANADA

STAFF CHANGES

Much has happened at the Institute in the years 1983 through 1985. A substantial reduction in staff occurred, largely as a result of the then Deputy Minister's announcement in July 1983 on reviewing and possibly revising the role of provincial forest research.

At the beginning of 1983, there were 54 classified and 38 unclassified staff. By December 1985, the classified staff had dropped to 40 and the unclassified to 30. During this time, the Institute was very fortunate in being able to participate in a number of job creation programs. Highly qualified people were recruited and the scientific programs did not suffer as severely as might have happened.

D.N. (Dave) Bates joined OTIFBI from the Ontario Centre for Remote Sensing in January 1983 as the Technology Transfer specialist to assist in the dissemination of research knowledge to the forest managers.

1983 saw several members from the administration unit leave the Institute. J.G. (John) Boufford went to Systems Services Branch at head office, although his prime function remained the servicing of OTIFBI's computer needs. S.R.A. (Steve) Gourlay, the Executive Officer, went to Forest Resources Group at head office. S. (Sandy) O'Neill resigned and I.(Isobel) Palmer retired. D. (Diana) Morgan joined the staff on long-term contract to replace Steve Gourlay as Executive Officer. F. (Frank) Lozano and A. (Alex) Mosseler terminated long-term contracts to begin employment with the Faculty of Forestry at the University of Toronto.

In 1984 L.J. (Lillian) Bowdery, secretary at the Midhurst Research Station, and R.H. (Ray) Leech, our tree nutritionist, retired. D.A. (Don) Boufford went to the Orono Nursery, and C. (Chandra) Gocool went from OTIFBI's site laboratory to Sports and Fitness Branch of the Ministry of Tourism and Recreation. Dr. L. (Louis) Zsuffa, Principal Scientist, resigned to head the forest genetics program of the Faculty of Forestry, University of Toronto. D.C. (Don) MacIver, a biometrician on long-term contract, left the Institute and took a position with Timber Sales Branch at head office. In 1984, the Institute, and particularly the jack pine program, benefited with the arrival of Dr. Csaba Matyas as a visiting scientist from Hungary. He was with us for one year involving himself in jack pine provenance evaluations for tree improvement and operational program use.

Some very significant changes took place in 1985. The Mensurational research unit under A.F. (Al) Beckwith was transferred to Timber Sales. Al was accompanied by D. (Dave) Andison, P. (Peter) Roebbelen and M. (Murray) Woods. Peter resigned and took a position outside government at the time of the transfer.

G. (Geoff) Pierpoint, site research scientist, was also transferred to Timber Sales, along with P. (Peter) Uhlig, who had recently joined us on a long-term contract. Dr. F.L. (Frank) Raymond, our biometrician, was transferred as well to Timber Sales at head office. Dr. D.C.F. (Dave) Fayle, tree root scientist, and J.V. (Jim) Hood, population geneticist, were transferred to Forest Resources Branch as coordinator of technology development and technical coordinator of forest genetics and tree improvement respectively. E.M. (Edna) Beckwith, purchasing

accounts coordinator, retired and was replaced by D. (Don) Watson from North Bay District. O. (Olga) Kent, who had been with forest research since 1954, retired from her secretarial duties. J. (Jo) Stoddart, laboratory technician with Dr. C. (Chris) Glerum, also retired, and Dr. C.P. (Ernie) Chen came on classified staff to work in Chris' lab. He had been with Harvey Anderson on long-term contract. S.J. (Sandy) Lindell, laboratory technician in the forest genetics laboratory, resigned for a position outside government.

Five long-term contracts were commenced in 1985: M.A. (Ann) Baird in the biotechnology section with Dr. Ho; K.A. (Karen) Fischer with Dr. Buchert in forest genetics; and D.F. (Dennis) Hickie, R.S. (Ross) Koppenaal and K.D. (Kerry) Odlum with Dr. Glerum and S.J. (Steve) Colombo in stock production.

K.M. (Keith) McClain was on educational leave from 1982 to 1984 at Oregon State University. Keith was studying seedling physiology relative to survival and growth on droughty sites.

And finally, D.A. (Doug) Skeates, seed research scientist, went to Thailand for one year under the auspices of the Canadian International Development Agency. Doug was responsible for the formation of a regional forest tree seed centre near Bangkok to serve Thailand, Indonesia, Singapore and the Philippines.

ONTARIO TREE IMPROVEMENT AND FOREST BIOMASS INSTITUTE

D.P. Drysdale - General Manager
P. Mueller Secretary

Administrative Support Unit

D. Morgan* - Executive Officer
M. Johnstone
J. Kucopy
D. Watson
B. Morrell
J. Tonge

Technology Transfer

D. Bates - Technology Transfer Specialist
J. Robinson

Systems Support

F. Matejka**

Tree Improvement and Biomass Section

G. Buchert - Principal Scientist
S. Brenham (Secretary)

Forest Biomass Unit

H. Anderson (Leader)
K. Roberts
W. Beekers
D. Weingartner
P. Jaciw
C. Papadopol*

Tree Improvement Unit

G. Buchert (Leader)
M. Weishar
T. Taylor
L. Daisley*
L. Farintosh*
J. Wild*
D. Skeates
D. Irving
A. Gordon
N. Jondreau
N. Lussier
M. Famiglietti
H. Ho
M.A. Baird*
Y. Raj*

Nursery/Greenhouse/ Arboreta Unit

K. Bennett (Leader)
D. Gamble
J. Byrnes

Forest Ecology and Silviculture Section

D. Burger - Principal Scientist

Site and Productivity Unit

D. Burger (Leader)
L. Spence
G.B. MacDonald

Silviculture and Tree Biology Unit

C. Glerum (Leader)
J. Paterson
Y.T. Kim
C.P. Chen
R. Hutchison
G. Racey*
G. Stroempl
S. Colombo
M. McLean
W. Ohlmann
I. Palmer
K. McClain
N. Knudsen
T. Casella
R. Forslund
G. Robinson

* Long-term Contract Positions
** Systems Services, Toronto

December 31, 1985